Mechanical and Physical Risk Prevention

Studies and Research Projects

REPORT **R-858**

Wind Energy Sector

Occupational Health and Safety Risks and Accident Prevention Strategies

Jean-Louis Chaumel
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Adrian Ilinca

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PEER REVIEW

In compliance with IRSST policy, the research results published in this document have been peer-reviewed.

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In addition to publication of our findings, the project has also resulted in a number of changes and advances in workplace accident prevention at several wind energy organizations and companies. We wish to assure those who supported and took part in this innovative project that their contributions have had a tangible beneficial impact.

ABSTRACT

Despite very strong worldwide growth in the number of installed wind turbines, particularly in Quebec, work accident statistics remain fragmentary, even internationally, and are not indicative of the status of occupational health and safety in the sector. The purpose of this study was to gain a better understanding of occupational health and safety risks and practices, as hundreds of high-power wind turbines are being built each year in Quebec. The overall aim was to provide a general assessment of the wind energy industry.

The study used a multipronged approach, as opposed to statistical analysis alone, to identify, describe and analyse the accident risks in the sector, as well as the prevention practices and compliance of these practices with those recommended by the Commission de la santé et de la sécurité du travail (CSST) [Quebec's occupational health and safety board]. To our knowledge, this is the first study to draw up an occupational health and safety profile of employees working in or in connection with this industry.

The study findings begin with a review of occupational accidents that have occurred in the industry since the early 2000s. It should be noted that in addition to the hazards associated with the mechanical aspects of wind turbines, workers also face cardiac risks and the electrical hazards associated with power circuits and control circuits. These are two quite logical findings because not only is the work usually performed at heights, but many of the hazards are electrical, as a wind turbine is essentially an electrical generator.

The accident prevention programs found are an odd assortment and come in many forms, often simply borrowed from wind turbine manufacturers, none of which are based in Quebec. No clear, instructive examples of related practices from elsewhere in the world were found, either. Companies operating in Quebec should therefore shift towards implementing adapted prevention plans that comply with Quebec legislation and CSST requirements. To analyse on-site working conditions, the researchers spent time observing technicians performing their operation and maintenance tasks, as well as construction companies and subcontractors during the wind farm construction phase. These observations served to supplement the data collection and characterize work hazards and procedures.

Lockout, as defined for machinery in Quebec, is not applicable as such in the wind energy sector. The study established an initial framework for applying reinforced measures that are clearer for workers, but also adapted to the unique context of wind turbines, which are in fact electrical generators located high above the ground.

Lastly, winter work in isolated locations, which is characteristic of jobs in the Quebec wind energy industry, presents challenges that can only be addressed in a way that reflects Quebec realities. The predominant issue is how to help and quickly evacuate injured workers when rescue services are so far away. The research identified problems such as ambulance response time and airlifting, and laid the groundwork for potential improvement strategies.

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1. INTRODUCTION

1.1 Current Situation

The first wind turbines in Quebec were installed about 10 years ago, when a 133-unit farm was commissioned. The Quebec government recently moved to speed up wind energy development and Hydro-Québec launched three consecutive calls for tenders of 1,000 MW, 2,000 MW and 500 MW for community and First Nations projects. In September 2013, installed wind power capacity in Quebec was 1,866.2 MW, according to the Wind Energy TechnoCentre.[1] By 2014–2015, close to 3,000 wind turbines—mini-electrical generators perched on top of 80 to 100 m masts—will be operating in the province. Operating and maintaining these wind farms will keep over 1,000 people employed full time, and another 2,000 part time.

A wind farm is an electrical power station consisting of individual generating units spread across a fairly extensive geographic area. In need of constant winds, most farms have been established in mountainous, isolated regions far from urban centres. The wind farm construction period, a relatively short two years, is a very different kind of activity from the more than 20-year operating period. Both installation and operation require specialists from different trades to work at heights of up to 100 m, as most of the electromechanical systems are located in the nacelle at the top of the tower. These complex technical systems require frequent maintenance by technicians with a broad range of skills who are not only able to work in isolation, in cramped spaces, but are also capable of considerable physical exertion.

Thus, working at heights, sometimes in tight areas similar to confined spaces, isolation, lack of nearby emergency response capabilities, the physical demands of climbing towers, working in very cold temperatures, the risks of electric shock or electrocution, but also a lack of hands-on training and inadequate preparation of casual workers, are all factors in wind turbine occupational health and safety (OHS). The prevalence of some of these risk factors was still only hypothetical. These are the many issues this research project set out to explore.

The fact that the industry is so new to Quebec and, more importantly, the lack of statistics on industrial accidents and occupational diseases have hampered the adoption of suitable accident prevention measures and training methods. As a result, Quebec has fallen behind current practices in Europe and the United States, where the largest concentrations of wind turbines are found. Moreover, the working conditions specific to Quebec, such as harsh winter weather and the remoteness of some farms, would logically appear to increase the risks for workers, although neither the extent of the risks nor the specific accident prevention measures that should be implemented are known.

In short, to improve industrial accident and occupational disease prevention in this new sector, certain gaps in the OHS statistical data available need to be filled, and more needs to be learned about the reality and risks of working in this industry in Quebec.

1. https://www.eolien.qc.ca/en/eolien-in-quebec/wind-farms-in-quebec.html, accessed September 17, 2013.

1.2 Study Objectives

The purpose of this study was to advance our knowledge about occupational health and safety issues in this emerging renewable energy sector in Quebec. As a literature review did not turn up any studies on health and safety in the sector, the objective pursued jointly by a team from the Université du Québec à Rimouski (UQAR) and researchers at the Institut de Recherche en Santé et Sécurité au Travail (IRSST) [Quebec's occupational health and safety research institute] was an ambitious one. The research method was based on a coordinated, multi-strategy approach in which statistical analysis was extensively supplemented by studies, especially field studies, focusing on people and organizations in the sector.

The project had five stages:

- Analysis of wind turbine accidents around the world
- Review of existing accident prevention plans (Quebec, other Canadian provinces, U.S.A. and Europe)
- Brief assessment of work situations during wind farm construction, operation and maintenance
- Study of wind turbine lockout
- Examination of means used to evacuate injured workers from wind farms and of conditions affecting such evacuations

Our purpose in documenting this reality and compiling more comprehensive scientific information was to be able to make recommendations tailored to Quebec that would help improve accident prevention.

2. ACCIDENT AND INCIDENT ANALYSIS

2.1 Background

The existing accessible databases on accidents in the wind energy sector have historically been developed by groups opposed to the deployment of wind turbines and which, by publishing information about accidents, hoped to highlight what they saw as the dangers of wind energy technology.[2]

In most cases, the data refer primarily to mechanical accidents to wind turbines, but provide no information about workers. The reliability of the reports is very questionable. For instance, the particularly high number of accidents involving turbine blades (1/300 turbines) actually includes accidents that occurred in blade manufacturing plants or during blade transportation, and not just accidents associated with wind turbine operation.[3] Furthermore, insurers too must identify risks. Some insurers estimate that, on average, they pay out compensation for one accident every four years (Ragheb & Ragheb, 2011).

2.2 Actions and Method

Given the lack of statistics on workplace accidents in the wind energy sector, both in Quebec and elsewhere in North America, we decided to take a two-pronged approach. We began by getting in touch with what used to be called the British Wind Energy Association (BWEA), but now goes by the name RenewableUK, which keeps a record of accidents. Second, we analysed the information in the database of the Caithness Windfarm Information Forum (CWIF), which is fighting against the proliferation of wind turbines in Scotland, especially in the Highlands.

In the first case, despite filing a formal request with RenewableUK to analyse and use the accident report data and despite registering the IRSST as an academic member of the association, we were refused access to the data. Note, too, that RenewableUK also has a health and safety working group, but it was not very active between 2009 and 2012.

In the second case, the database can be accessed publicly through the association's website.[4] We therefore carried out an analysis of the CWIF database, one of the few to be publicly accessible. The data are compiled by the association through a review of the international press, but focusing chiefly on the U.K. media. Accident coverage appears to be more complete for countries such as the U.S.A., the U.K. and Germany than for France or Spain, for instance. The association's database, which seeks to record all wind turbine accidents that occur, is updated several times a year. A wide range of sources are used, including newspaper articles, the site

2. One of the largest databases of this kind contains information about accidents documented in the media or in police reports from around the world: https://www.wind-watch.org/news/tag/accidents/.

3. This Belgian database compiles information chiefly about wind farms in northern Europe: http://www.leseoliennes.be/parceolien/accidents.htm.

4. http://www.caithnesswindfarms.co.uk/index.htm.

www.windaction.org[5] and wind farm operator annual reports. The compiled data are therefore not the result of a systematic collection procedure conducted by a specialized OHS agency. They do not allow connections to be drawn between numbers of workers and accident frequency. The data are also very imprecise with respect to workers' exact injuries.

This lack of information about workplace accidents in the sector is similar to the lack of information on wind turbine fires (Starr, 2011). In the latter, non-scientific article, the CWIF database is likewise used for reference purposes, even though the author does point out that it underestimates the real number of wind turbine accidents or incidents. The reasons for the underestimation (remoteness of sites, unsystematic use of emergency services, lack of official records regardless of the magnitude of the incident, etc.) cannot be transposed directly to workplace accidents, but do appear to be similar. For instance, a study by Le Métayer (2004) indicates that wind turbine maintenance companies are sometimes classified in very diverse sectors, such as "fixed heating costs for buildings" or "miscellaneous industrial equipment supply and wholesaling." An accident analysis by industry conducted by regulatory OHS insurers (CSST in Quebec, CRAM in France, etc.), therefore cannot link accidents involving these companies to the wind energy sector. Another example of the problems encountered in identifying accidents connected with wind farms is an OSHA (2003) report that does not provide any specific information about where each accident occurred. Even if the cause is specified (e.g., an object falling from a wind turbine tower), it is impossible to link the accident to a specific wind farm.

To our knowledge, no OHS agency anywhere in the world keeps statistics on accidents in the wind energy sector, and no scientific publication provides related statistical or descriptive data. Moreover, the fact that workplace accident reporting is not standardized from one country to the next makes it very difficult to conduct a valid international statistical survey for the sector.

2.2.1 Building OHS Database Starting with CWIF Data

Given that existing databases have a much broader scope than purely occupational health and safety, the research team had to put significant effort into restricting the selection criteria and developing a database devoted specifically to workplace accidents. The initial CWIF data were supplemented by new data collected by the research team (accidents in Quebec or elsewhere, but not included in the data).

The initial database had eight types of information:

- Type of accident
- Date
- Place
- Country
- Type of wind turbine
- Accident details

5. The Industrial Wind Action Group was established to refute misleading information disseminated by the wind energy industry and various environmental groups. Its efforts are supported by an extensive, diverse group of ecologists, energy experts and regular citizens.

- Source of information
- Web link

Accidents were classified into 11 categories:

- Fatal
- Blade failure
- Mechanical failure
- Structural failure
- Human injury
- Lightning
- Environmental
- Fire
- Ice throw
- Transport
- Miscellaneous

After analysing the database, we excluded five accident categories (blade failure, structural failure, lightning, environmental and ice throw) from our study, as they concerned the general public. As a result, we kept the following six worker-related categories: fatal, mechanical failure, human injury, fire, transport and miscellaneous. In doing so, we went from 994 general accidents to 133 OHS accidents for the years 2000 to 2010, as of April 6, 2011. These are industrial accidents involving one or more workers that occurred in or close to the wind turbine, or accidents that occurred when handling or transporting wind turbine components. Accidents that occurred in factories or at wind turbine manufacturing sites were deleted from the database.

We then added three types of more specific information (Table 1) to the database to allow more precise processing:

- Accident details (number of workers involved, type of accident, nature of task workers were performing, certainty about nature of task)
- Wind farm location
- Wind farm characteristics (construction date, number of turbines, unit power of turbines)

Table 1 – Information added to database

Information added	Details about information	Explanation
Number	Number of people injured or killed in same accident	With the initial database, it was impossible to know exactly how many people were injured or killed (e.g., a single accident can result in one fatality and several injured).
Type of accident	Impact Fall (of person) Crane fall or collapse Falling object Contaminant Physical exertion Electric shock Explosion Fire Sea Moving part (mechanical) Traffic Temperature (cold, heat) NOS (not otherwise specified)	Accidents were classified by hazard involved (“sea” for drowning, for instance).
Nature of task	Research/exploration Transport Construction Operation Maintenance NOS	The nature of the task was determined by comparing the details of the accident with the date the wind farm was built. This information situated the accident in the turbine’s life cycle.
Certainty about nature of task	1 = nature of task certain 0.5 = nature of task deduced	Certainty refers to our degree of confidence in our knowledge of the nature of the task, based on a reading of the details of the accident. For instance, if the source said “worker in turbine,” with no other details available about the construction of the unit, then “nature of task” = maintenance, and “certainty of task” = 0.5.
Location	On shore Offshore	Used to distinguish between on-shore and offshore farms.
Construction date		Used to determine age of farm.
Number of turbines		Provides indication of size of farm.
Power (MW)		Unit power of turbines installed at farm.

2.2.2 Tracking New Accidents

As it was very difficult to obtain reliable data from existing North American and European databases, we decided to collect our own data over the course of the 15 months of the research project (October 2009–January 2011). This proactive international monitoring process, using the World Wide Web and information provided by industry, was structured as follows:

- Monitoring control centre: UQAR, Clément Guitard and Jean-Louis Chaumel
- Second monitoring station: IRSST, Laurent Giraud and Sabrina Boucenna
- European monitor: Than Hua, safety manager at Theolia, a project consultant
- North American monitor: Peter Golbeck, wind turbine safety specialist, a project consultant

Data on 15 accidents collected through this monitoring process were added to the initial CWIF data on 133 accidents. The database is reproduced in Appendix A.

2.2.3 Translation of Accident Reporting Form and Use on Trial Basis to Collect Data

An accident reporting form was available on the RenewableUK website when the research was conducted in 2009. The organization used the form to collect information, provided on a voluntary basis, on accidents primarily in the United Kingdom and continental Europe. RenewableUK also issues safety warnings, but only infrequently: five were issued in December 2008, one in April 2009 and the last one dates from September 2009.[6] Since the end of 2012, this information-sharing system has been reorganized under the acronym RISE (Renewable Industry Safety Exchange),[7] but it is still strictly limited to wind energy sector partners who are organization members.

The research team translated and adapted the RenewableUK form (Appendix B) and used it to collect data on a limited number of industrial accidents. Translation and use of the form initially suggested that it was well structured, but experience showed that it was very difficult to fill out when the respondent was not in direct contact with the place where the event occurred. In addition, the form did not provide a means of connecting an accident with a specific wind farm, as reporting was done anonymously, which made it impossible for the researchers to conduct any analysis linking the actual work activity with the organization and its resources (Lamonde et al., 2010).

2.3 Analysis and Summary of Findings

As the database (Appendix A) we developed shows, the total number of accidents from all sources is still quite small, given the large number of turbines in operation in the countries

6. Site www.renewableuk.com, accessed June 10, 2011.

7. http://www.renewableuk.com/en/our-work/health-and-safety/incidents--alerts.cfm, accessed September 17, 2013.

monitored by the association. The CWIF data do not contain any record of an accident in Quebec. This would seem to suggest public underreporting of accidents, as the evidence gathered from partners during the study indicates that at least one electrical accident has indeed occurred in Quebec since the most recent wind farms (1 MW or more) went into commercial operation. Other "near accidents" have also been noted in Quebec, including a large chunk of ice falling onto a work vehicle at an operating wind farm.

2.3.1 Nature of Task

A total of 287 workers were involved in the 148 accidents listed in Appendix A. Table 2 gives the breakdown of accidents and workers by type of accident and nature of task being performed. There have been a few more fatal accidents connected with wind turbine *maintenance* (14) than *construction* (12). In one case out of 34, two workers died in the same accident.

In the "miscellaneous" accident category, 86 workers were involved in seven *construction* accidents, whereas three workers were involved in three *maintenance* accidents. The high number of workers involved in "miscellaneous" *construction* accidents includes two accidents that involved boats or barges for offshore wind farms.[8]

In the "injury" accident category, there were 3.7 times more *maintenance* accidents (55) than *construction* accidents (15). All in all, these two subcategories accounted for 86% of the workers in the "human injury" category. Multiple-victim accidents, involving two to four workers, were much more common during the *maintenance* phase than during the other wind farm life-cycle phases (see Table 3). There were 12 *maintenance* accidents, 4 involving four workers each, 2 involving three workers each, and 6 involving two workers each, for a total of 34 workers involved in 12 of the 19 multiple-victim accidents.

In the "transport" accident category, 17 workers were involved in eight *construction* accidents, 23 in 1 *maintenance* accident, and 11 in 10 *transport* accidents. Most of these accidents involved only one worker (i.e., the truck driver). A few rare accidents stand out from the rest: the *maintenance* accident mentioned above, in which 23 workers had to be evacuated from a stricken barge, a *construction* accident involving 10 workers, in which a barge carrying a giant crane sank during transport, and a traffic accident involving two workers, in which a truck collided with a train. There is a certain ambiguity to this category, however, as the data could also be classified in another category. It was decided not to recode the category, but rather to use it cautiously.

8. One barge had to be evacuated in 2007 (38 workers) and another in 2009 (42 workers).

Table 2 – Accidents, by type and nature of task

	Workers	Accidents
Fatal	**35**	**34**
Construction	12	12
Maintenance	14	14
Research	4	3
Transport	1	1
NOS	4	4
Miscellaneous	**89**	**10**
Construction	86	7
Maintenance	3	3
Injury	**106**	**82**
Construction	17	15
Miscellaneous	4	4
Operation	3	2
Maintenance	74	55
Research	3	2
Transport	1	1
NOS	4	3
Fire	**6**	**3**
Maintenance	6	3
Transport	**51**	**19**
Construction	17	8
Maintenance	23	1
Transport	11	10
Total	**287**	**148**

Table 3 – Accidents involving more than one worker, by type of injury

Workers involved	Construction	Operation	Maintenance	Research	Transport	NOS
4			4			
3	1		2			
2	1	1	6	2	1	1

2.3.2 Cause of Accident

Figures 1 and 2 give the breakdown of the number of accidents and number of workers involved by accident cause. They show there were almost as many traffic accidents (23) as worker falls (24). The other causes, in order of importance, were electric shock (16), moving part (15), falling object (14), impact (13), fire (7), physical exertion (7), sea (6), crane collapse (6), explosion (2) and contaminant (1).

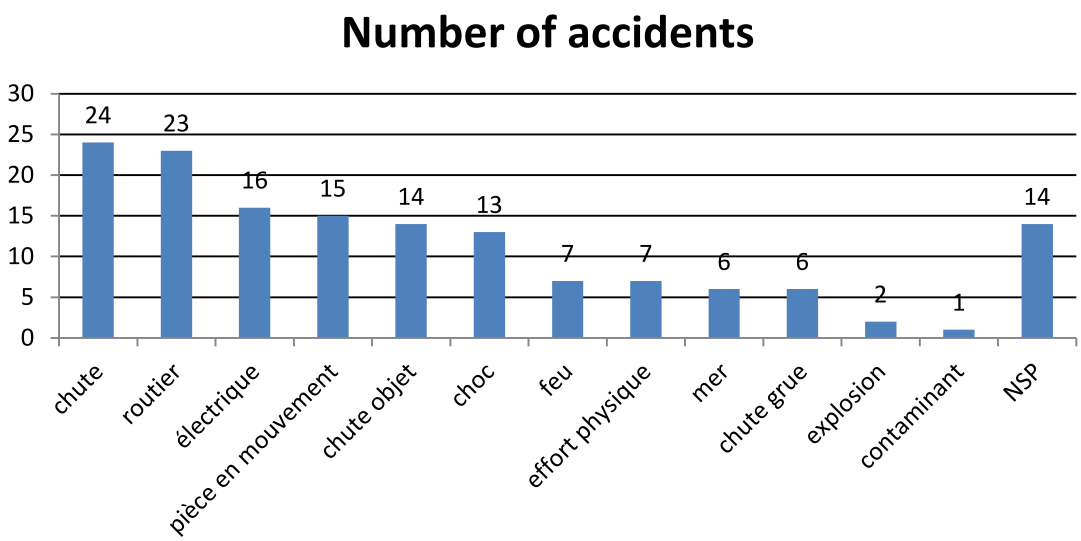


Figure 1 – Accidents, by cause

Note that the cause “sea” stands out immediately in terms of number of workers involved (Figure 2), as 113 workers were associated with four accidents having this cause: two transport accidents affected 33 workers, while two miscellaneous accidents involved 80 others.

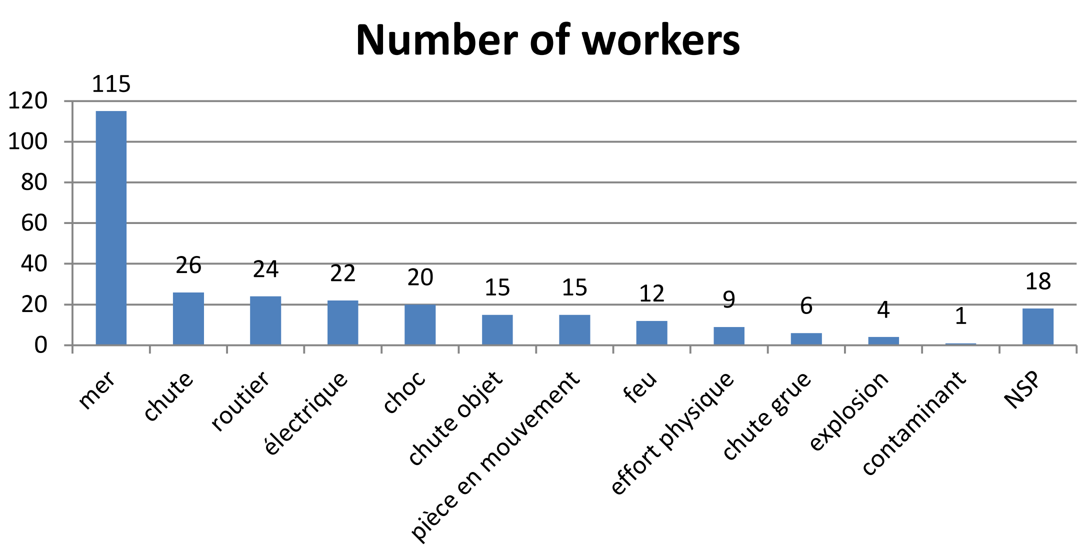


Figure 2 – Workers involved, by cause

Except for the special case of the sea, the order of importance of the causes changes only slightly when the number of workers involved is considered rather than the number of accidents. Thus, more workers were involved in falls (26) than in traffic accidents (24). The other causes, in terms of the number of workers involved, were electric shock (22), impact (20), falling object and moving part (15), fire (12), physical exertion (9), crane collapse (6), explosion (4) and contaminant (1).

Figure 3 shows the number of worker fatalities by cause, while Figure 4 gives the number of workers injured by cause. The prime cause of fatalities (35) was falling (10) and the second biggest was traffic accidents (6). The number of fatalities classified as accidents with unspecified causes was high (7).

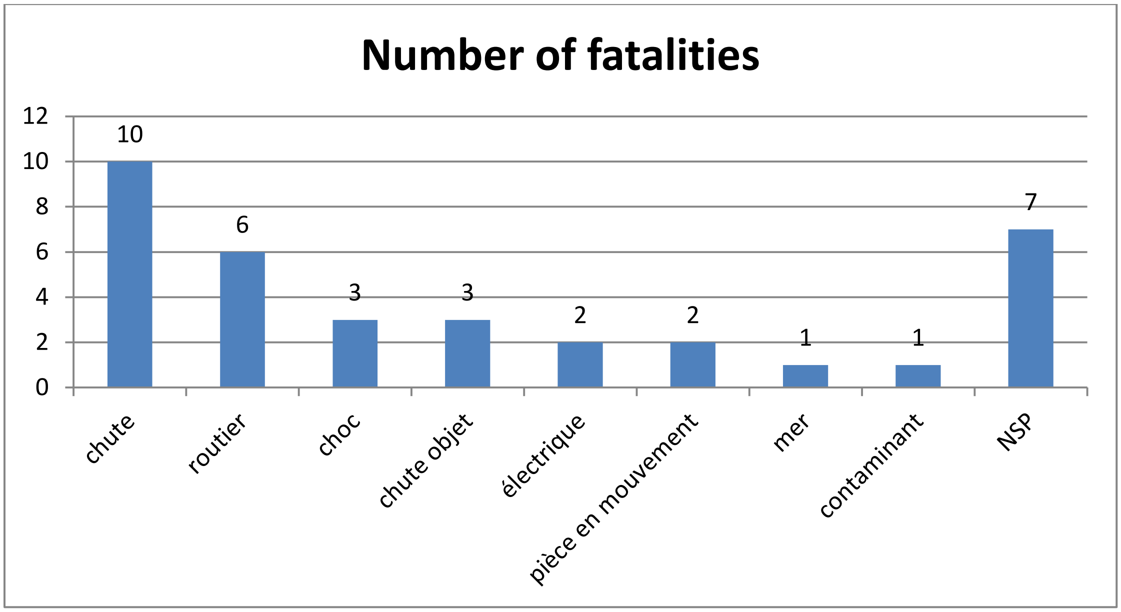


Figure 3 – Fatalities, by cause

The breakdown of injured workers (106) by cause (Figure 4) differs sharply from the preceding classification. The two causes involving the greatest number of workers were electric shock (20) and impact (17), followed by falling (15). The other causes of injury, by order of importance, were moving part (13), physical exertion (9), falling object (7), fire (6), crane collapse (4), explosion (4) and sea (1).

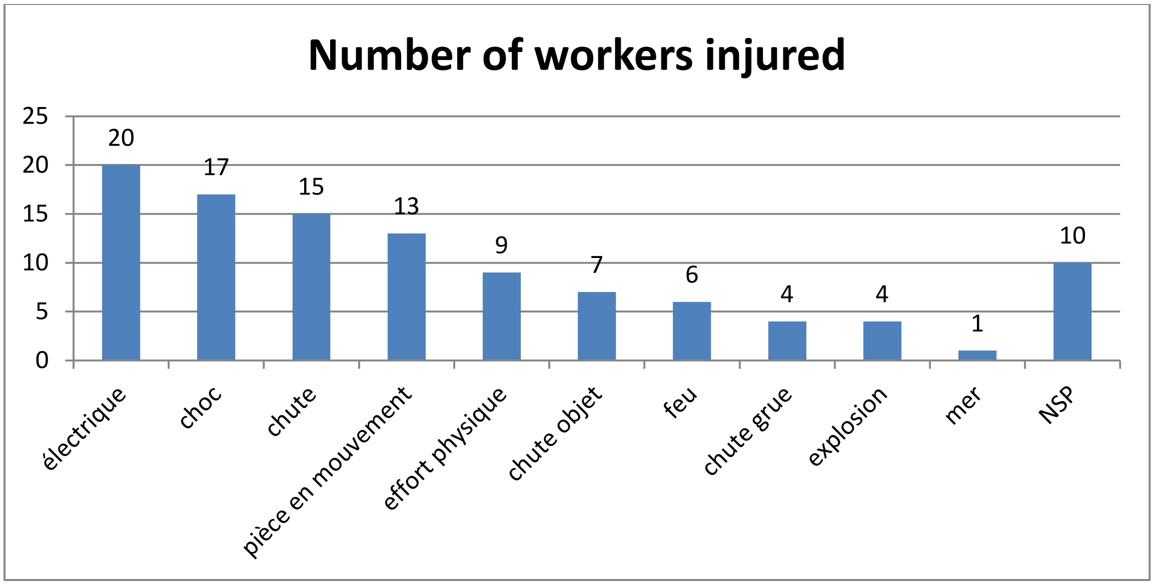


Figure 4 – Workers injured, by cause

By combining the “fatality” and “injury” categories, which together account for 116 of the 148 accidents that directly harmed 141 workers in the wind energy sector, we arrived at the following list of causes by order of importance:

1. Falling (25 workers)
2. Electric shock (22)
3. Impact (20)
4. Moving part (15)
5. Falling object and physical exertion (10 and 9 respectively)
6. Fire and traffic (6 each)
7. Explosion and crane collapse (4 each)
8. Sea (2)
9. Contaminant (1)
10. NOS (17)

If the “transport” category, which corresponds primarily to the turbine construction phase and which caused indirect harm to another 51 workers, is included (bringing the total number of accidents accounted for to 135 out of 148), then the order of importance of the causes is as follows:

1. Sea (35 workers)
2. Falling (25)
3. Traffic (24)
4. Electric shock and impact (22 and 20 respectively)
5. Moving part (15)

6. Falling object (10)
7. Physical exertion (9)
8. Fire (6)
9. Explosion and crane collapse (4 each)
10. Contaminant (1)
11. NOS (17)

In this case, there are two notable differences, with sea accidents now ranking first (+33 workers) and traffic accidents third (+18 workers). Falling remains in second place, while the order of the other causes is unchanged.

Given that Quebec does not have any offshore wind farms and that wind turbine construction is a transitory stage, the order of causes given by the categories “fatality” and “injury” is more representative of the Quebec situation. The order makes sense if the work environment (working at heights on a mechanical system designed to generate electricity) and nature of the work (turbine inspection, dismantling, reassembly, etc.) are considered.

3. ANALYSIS OF WORKPLACE REALITY

This description of real working conditions in the wind energy sector is based on an analysis of the data collected during three field observation periods. In the first period, the UQAR research team observed the building of the Rivière-au-Renard wind farm (Wind Energy TechnoCentre) in December 2009 (construction phase). Owing to the start date and duration of the research project,[9] this was the only one that could be observed during construction. The final winter phase (installation of the turbines within a very tight time frame), carried out in cold weather conditions typical of Quebec in winter, was observed (see Appendix C). In recent years, the CSST has been concentrating its accident prevention efforts on wind farm construction sites because the new sites involve large numbers of workers handling outsize equipment in isolated regions.

The joint IRSST-UQAR research team conducted two further observation periods of scheduled wind farm maintenance operations in 2010, in order to cover the operating and maintenance phases. In addition to these observation periods, two meetings were held, away from the farms, with executive or OHS officers of two wind energy subcontracting companies, as well as discussions with organizations associated with the sector, such as the CSST. Knowledge gleaned by IRSST researchers from visits to other wind farms in connection with preparing activity estimates was also incorporated into the report.

3.1 Training of Maintenance Employees

There is only one wind energy maintenance vocational training program in Quebec. It has been offered at the Gaspé CEGEP, on the Gaspé Peninsula, for a number of years now. As the program does not have the capacity to meet the demand for all the jobs available, however, students in training are regularly snapped up by employers even before they finish their courses. Information gathered on visits to wind farms and in discussions with wind energy subcontractors in Quebec indicates that operators are currently facing a shortage of trained technicians who can work on their own, with the result that subcontractors are hiring general mechanics and electricians who have no specific training in working on the most recent turbine models. After analysing the available data, we concluded that the Quebec wind energy sector is entering a critical period with respect to the availability of qualified, trained maintenance personnel. This situation already seems to be the case in the United States (Gill, 2008)[10] and elsewhere in the world (Truc, 2008). The Quebec shortage is likely to continue, if not worsen, with the construction of the farms of the second (2,000 MW) and third (500 MW) calls for tenders, which will progressively be commissioned between now and 2015 (Table 4).

9. Most of the wind farms of the first call for tenders had already been built, while work on the farms for the second call for tenders was at the civil engineering preparatory stage (building the access roads and readying the sites where the turbines would be erected).

10. http://www.orosha.org/admin/newsrelease/2008/nr2008_05.pdf.

Table 4 – Commissioning of Quebec wind farms

Wind farm	Call for tenders	Date commissioned
Montagne-Sèche, Mont-Louis (39, 67)* De l'Érable, Des Moulins, Saint-Robert-Bellarmin, Le Plateau (50, 78, 40, 60)	1st 2nd	2011 2011
Gros-Morne (141) Saint-Valentin, Massif-du-Sud, Saint-Rémi, New Richmond (25, 75, 44, 33)	1st 2nd	2011 & 2012 2012
Lac-Alfred (150) Seigneurie de Beaupré 2 and 3 (63, 68) Le Plateau 2, Viger-Denonville, Saint-Damase (10, 12, 12)	2nd 2nd 3rd	2012 & 2013 2013 2013
Seigneurie de Beaupré 4, Vents du Kempt (30, 43) Le Granit, Saint-Philémon, Témiscouata, La Mitis (12, 8, 11, 12)	2nd 3rd	2014 2014
Clermont (12) Côte-de-Beaupré, Frampton, Pierre-De Saurel, Saint-Cyprien, Val-Éo (n/a, 12, 12, 8, 8)	2nd 3rd	2015 2015

*Numbers in parentheses indicate number of wind turbines per farm (n/a: not available)

According to the Canadian Wind Energy Association (CANWEA), three other institutions in Canada have training programs equivalent to the one offered at the Gaspé CEGEP:[11] Lethbridge College in Alberta, Northern Lights College in British Columbia and Great Plains College in Saskatchewan. A dozen or so other training programs related to renewable energy, including wind energy, are also offered across Canada. Bury (2011) argues that, despite CANWEA's optimistic public statements, it will be hard to meet all the demand for qualified workers in this industry over the coming years.

Figures concerning the workforce required to maintain the new wind turbines (1.5 MW and larger) differ from one source to the next. Bury uses the ratio of one technician per 2 MW of energy generated, while Poore and Walford (2008), who conducted their study for the National Renewable Energy Laboratory (NREL) in the United States, indicate that one technician can take care of 10 turbines, which is a ratio of one technician per 20 MW. However, the NREL study's findings can also be used to calculate the number of other people required to operate a wind farm (operations manager, support employees, etc.) based on person/megawatt ratios. An Industry Canada report (2004)[12] on the human resources needs of the Canadian wind energy industry forecast that 2,231 people would work in the wind energy sector in Canada by 2012, for anticipated installed power of 5,645 MW, which works out to a ratio of one person for every 2.5 MW of installed power. Nevertheless, given the problems involved in getting from one farm to another in Quebec, especially in winter, it would be more realistic to use a ratio of one technician for every 10 MW of installed power, which would work out to approximately 400 maintenance technician jobs in 2015. Thereafter, this number would have to increase, as wind

11. http://www.canwea.ca/pdf/EducationandTrainingPrograms.pdf, updated June 2012, accessed September 17, 2013.

12. Government of Canada, *A Study of Supply-Chain Capabilities in the Canadian Wind Power Industry*, November 2004, available on the Wind Energy TechnoCentre website: https://www.eolien.qc.ca/en/documentation-en/studies.html, accessed September 17, 2013.

turbines are mechanical machines that require increasingly frequent servicing as they age (Poore & Walford, 2008; Andrawus, 2008).

Wind farm size in Quebec contrasts sharply with the size of those in France, which is another factor influencing the organization of farm maintenance. At the end of 2009, France had 2,627 wind turbines in 446 farms,[13] for an average of six turbines per farm, with average installed power per farm of close to 14 MW. In Quebec, the farms resulting from private contracts and the first two calls for tenders operate an average of 70 turbines each, for a total installed power per farm of approximately 120 MW. With the third call for tenders, these figures will decline to 63 turbines and 91 MW per farm on average.

3.2 Key Components of Workplace Reality

Our findings on workplace design, work organization and OHS management are presented below. Working with the various players in the sector was not easy, and many of them required us to maintain a certain degree of confidentiality. In the end, we were able to secure the cooperation of only one wind farm operator and one turbine manufacturer, even though we assured all parties that we would maintain confidentiality.

3.2.1 Workplace Design

A wind turbine, and more specifically the nacelle, should be regarded as a workplace. Owing to a variety of factors — including rapid increase in turbine size, work organization and lack of feedback on operating experience from users to designers — facilitating maintenance is rarely taken into account when turbines are designed. Users' contribution to design, as mentioned in Standard ISO 12100, is still very limited.[14]

The wind turbines currently in commercial use are three-blade machines spinning on a horizontal axis located in a nacelle at the top of a mast. The nacelle itself moves on a vertical axis in relation to the mast, which is fixed, so it can swing to face the wind. The nacelle contains the turbine's main components. However, changes in turbine power have led to changes in nacelle design and thus in safety conditions (see Figure 5):

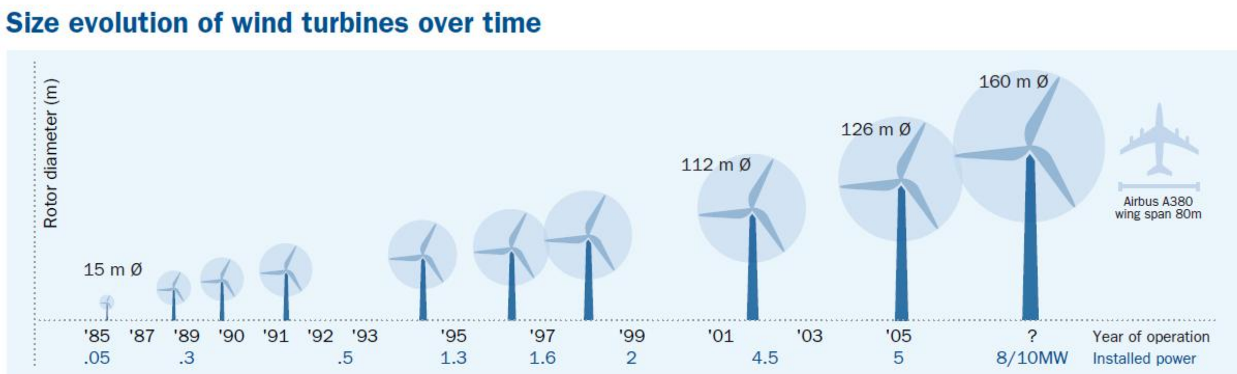
- For turbines of less than 300 kW, the nacelle houses only the turbine components, and maintenance personnel must remain on a platform outside to perform the work. Furthermore, the nacelle can only be reached from the outside of the mast, which means that workers are exposed to the weather and to a constant risk of falling.
- For turbines of 400 kW to 1.5 MW, the nacelle is large enough to accommodate maintenance personnel, but most of the tasks require opening the roof to provide enough room for working or lifting loads. While performing the tasks, maintenance personnel are

13. État des lieux du parc éolien français 2010, Syndicat des énergies renouvelables and France Énergie Éolienne, http://www.enr.fr/docs/2010170820_Parceolienfrancaisfindecembre09.pdf, accessed August 30, 2013.

14. *ISO 12100:2010 – Safety of machinery – General principles for design – Risk assessment and risk reduction*, (Geneva: ISO, 2010).

exposed to weather and to a constant risk of falling. The nacelle is accessed from inside the mast.

- On turbines of 1.5 to 2.5 MW, especially the older ones, the nacelle is large enough for maintenance personnel to enter and perform their tasks while protected from the weather. To gain access to the hub connecting the three blades, workers usually have to go out through the top of the nacelle and then enter the hub. For most tasks, workers are therefore not exposed to the weather or the risk of falling.
- For the most recent 2 MW turbine models, the nacelle is designed to allow maintenance personnel to enter and perform their tasks protected from the weather. Access to the hub is directly through the nacelle without having to go outside. Maintenance personnel are therefore not exposed to the weather or to the risk of falling, except if they must perform work on the nacelle roof.



Source: EWEA

Figure 5 – Changes in wind turbine size and power

In spite of improved working conditions for turbine maintenance personnel (e.g., the nacelles of the new models are usually designed so that workers do not risk falling), the inside of the nacelle is cramped and often dark, and the ergonomic parameters necessary to ensure good accessibility for maintenance are often not met. The nacelles do not have windows to let in natural light, meaning that artificial lighting, usually by means of fluorescent tubes, is required. Photographs and diagrams of nacelle interiors (Schreck, 2006)[15] show that there is very little room for workers to move around, that the floor is on several levels and consists of different materials (metal gratings, fibreglass, solid metal sections) and that work spaces are often very cramped.

Furthermore, ergonomics is not currently a research priority in the wind energy sector. Recent research has focused chiefly on offshore wind turbines and their reliability (Hendriks et al., 2000) and on the associated maintenance costs (Obdam et al., 2007; Rademakers et al., 2003), but little has been done to improve nacelles as workplaces. According to the EWEA, the top four wind turbine research priorities in 2009 were optimization of wind resources (forecasts, wind

15. http://rrbenergy.com/products/ps-1800-kw, accessed September 17, 2013.

turbine installation, etc.), wind farm reliability and output, integration of wind energy into the power grid and development of the European offshore sector.[16]

A fairly new wind turbine, generating around 2 MW and commissioned two to four years ago, requires 80 to 100 hours of maintenance per year, divided equally between preventive and corrective maintenance, and including restarting following a safety shutdown (Poore & Walford, 2008). The older a wind turbine gets, the more maintenance it needs, with the hours per year required almost doubling, to 160 to 200 hours, toward the end of its life. It is therefore quite conceivable for wind turbine designers to imagine that a maintenance worker will spend only a very short time (about 100 hours) in the nacelle of any given turbine. More generally, given the extensive training, technical qualifications and safety requirements that must be met before a technician can be authorized to perform turbine maintenance, operators seek to get the most out of their qualified personnel by maximizing the time they actually spend in the nacelle. For Quebec's wind farms, this means that crews of qualified technicians will spend several weeks in a row in the nacelles of all the turbines in a given wind farm, carrying out fall maintenance, for instance, or changing the lubricant in the speed multiplier. This means these workers will spend several months in the same physical workspace (the nacelle), even if they move to a new turbine every day. A nacelle should therefore be regarded as a workplace with all the design features required to ensure safe, healthy working conditions.

For example, climbing trolleys, used on the ladders of many Quebec wind turbines, were banned following a CSST ruling. The CSST acknowledged the apparatus's fall-prevention capability, but feared it could cause workers to lose their balance and hit their heads against the ladder. This decision, with immediate application, forced wind farm operators to add a second fall-arrest mechanism to all turbine towers concerned.

3.2.2 Work Organization

The major challenge, in terms of work organization for turbine maintenance, is the logistics of performing tasks in the nacelle. Due to the height of the nacelle and the limited means of access, work must be carefully planned.

In Quebec, workers reach the nacelle by climbing vertical ladders inside the masts. When it comes to rest platforms, this access does not meet the criteria of Standard ISO 14122-4:2004 for fixed ladders used as a permanent means of access to machinery.[17] The standard specifies that such ladders must have platforms every 6 m (10 m maximum for ladders without rest platforms) and staggered flights. In recently built wind farms in Quebec, however, the nacelle is reached by means of a single vertical ladder, without staggered flights, and the platforms are generally placed at the points where the different sections of the mast join. As a result, most access ladders have only four platforms at intervals of 20 to 28 m.

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16. http://www.ewea.org/fileadmin/ewea_documents/documents/publications/factsheets/EWEA_FS_Research.pdf, accessed September 17, 2013.

17. *ISO 14122-4:2004 – Safety of machinery – Permanent means of access to machinery – Part 4: Fixed ladders*, (Geneva: ISO, 2004).

Given this limited access, there can systematically be no more than two workers in the nacelle at any one time, in the interests of employee safety, while also ensuring that no worker has to perform work in total isolation (Guillemy et al. 2006). This reduced, or restricted, access also influences work organization. In Quebec, it is not unusual for maintenance technicians to climb up the mast in the morning and not come back down until the evening, having spent their whole day in the nacelle. This work organization has the following health, safety and work constraints:

- Food and drink are restricted to what the workers take up in the morning. There is very little possibility of eating hot meals.
- The temperature in the nacelle depends on the outside temperature, as it has very limited insulation and is exposed to the winds. Only the multiplier and the generator have thermal inertia that has a positive or negative effect on the temperature in the nacelle.
- Hygiene is restricted, as there is no water supply for washing hands or toilets.
- All the equipment must be taken up in the morning, which can require winching up several loads, then moving and positioning the equipment in the cramped space of the nacelle, thus increasing the risk of the workers stumbling when moving around.
- Any departure from the prescribed work plan means that a problem must be solved immediately: make do with the resources available, even if it means using whatever tool is within reach rather than the tool normally used to do the job (Grusenmeyer, 2000); ask a colleague to help, if that can solve the problem; make a trip back down to fetch the missing tool; or get a third person to bring it up.
- There is no direct supervision of work unless the supervisor climbs up to the nacelle after notifying the maintenance crew, which must be done in accordance with the safety procedures in force.

If workers could go up and down more often, some of these constraints would disappear. However, in light of what we learned during our research conversations with stakeholders, workers do not appear to be willing to make the extra effort to climb up and down. A comprehensive assessment that compares additional access constraints with potential health and safety gains would provide operators with more factual information for deciding on the best strategy to adopt.

Equipment is raised up using a winch located either inside or outside the mast. When the winch is outside, a load can be raised from the foot of the tower to the nacelle without going inside. Outside the mast, however, the load is susceptible to being buffeted by the wind. When the winch is inside, the load must first be moved inside the mast through the access door at the foot of the tower, then raised to just under the nacelle with the winch, before it is moved manually from the top of the tower (fixed part) to the nacelle (turning part). This last stage of the handling can take some time because the orientation of the nacelle varies with the direction of the wind. The advantage in this case, however, is that the load is protected from the wind. As the speed of the winch is limited,[18] equipment handling must allow for travel time with a load (going up) and without (going down).

18. In Quebec, raising a load from the base of a wind turbine tower to the nacelle can take four to five minutes.

Weather conditions must be taken into account when deciding if it is safe to access the turbine. In Quebec, three factors are considered: wind speed, whether there is ice on the turbine and whether there is lightning. To ensure worker safety, operators apply the following strategies:

- Wind speed
  - When very little or no wind, all operations are authorized.
  - When wind is moderate, access to the roof of the nacelle is prohibited (which can also prevent access to the hub), but all operations inside the nacelle are authorized.
  - When wind is strong, only access to the base of the tower is authorized (climbing the mast is not allowed).
  - When wind is very strong, approaching the turbine is prohibited.
- Ice suspected on turbine
  - The turbine is stopped remotely and turned so as to allow safe access to the door at the base of the tower.
- Lightning
  - If the lightning is outside of a "safety perimeter," the crews already at the farm are notified and must be prepared to evacuate the turbines.
  - If the lightning is happening inside the "safety perimeter," all work must be halted immediately and all workers must leave the turbines, if not the farm, depending on the weather conditions.

3.2.3 OHS Management

Currently, there are a number of wind energy operators of various sizes in Quebec, but all have large farms of over 50 turbines per farm. In 2015, a dozen or so small, community or paramunicipal operators will join the industry as a result of Hydro-Québec's third call for tenders. These smaller operators will oversee farms limited to 25 MW, i.e., around a dozen turbines.

Manufacturers impose formal OHS procedures and methods during the warranty period. These rules and procedures are stipulated in detail and take precedence over those of the operator. Nevertheless, the various conversations we had while conducting the research revealed that although these OHS management systems are highly developed, they can also be diverted from their intended purpose. The purpose of the systems is to ensure worker safety on a daily basis, but monitoring and updating them means filling out a lot of forms, which takes time and energy, and a crew's OHS performance is often assessed based on these systems. It can therefore be tempting not to bother documenting all incidents or near incidents that did not have any human consequences, as leaving them out saves time and does not increase the level of non-compliance. As a result, operator experience feedback is biased, and the ultimate objective of ensuring greater safety cannot be achieved with certainty.

But what happens when the warranty period expires and turbine maintenance is no longer done by the manufacturer? This is the major uncertainty hanging over all wind farms built recently in Quebec. At least four farms have no longer been covered under the manufacturers' initial warranty since November 2012: the two in Murdochville and two from Hydro-Québec’s first call for tenders, i.e., Baie-des-Sables and Anse-à-Valleau. The warranty period for a third farm from the first call for tenders, Carleton, expired in November 2013. Large operators will have the choice of developing their own OHS management procedures or methods, or working with tools developed by the manufacturers if the latter continue to provide maintenance. But what will happen with the small operators from the third call for tenders that have only a dozen or so turbines? Only time will tell.

4. ANALYSIS OF EXISTING ACCIDENT PREVENTION PRACTICES

4.1 Methodological Approach

The entire research team was involved in collecting data on existing accident prevention plans and practices, chiefly in France, Canada, the United States, the United Kingdom and Germany. In Quebec, the construction worksite of the Rivière-au-Renard wind farm (Wind Energy TechnoCentre, or WETC) was observed by the UQAR research team over the winter. Subsequently, the joint IRSST-UQAR research team conducted two observations of the maintenance operations of another wind farm. These field-observation periods provided an opportunity to assess technicians' conduct, OHS guidelines, and the existence and accessibility of accident prevention programs, i.e., the operational aspect of prevention plans.

Internationally, the work consisted in identifying all accident prevention guidelines, plans and programs relating to wind farms. Consultant Than Hua, safety officer at wind farm operator Theolia, made a very significant contribution in this regard.

4.2 Legal Obligations of Wind Energy Industry in Quebec

Legal obligations in Quebec, under CSST regulations:

> *All employers are encouraged to implement a prevention program. All workers must be made aware of the program. Such a program is mandatory for employers in certain activity sectors. It is also mandatory for all employers who belong to prevention mutual groups.*

CSST, Prevention program regulations, Chapter 3, Act respecting occupational health and safety

With respect to accident prevention, it is important to remember that there are two distinct phases to wind farm activity: construction and maintenance (during operation).

During the farm construction phase, the companies involved are regarded as being part of the construction sector and are therefore required to file an accident prevention program. Companies whose employees work inside the turbines, however, are exempted from the obligation because wind turbines enjoy special status in Quebec, being regarded as "machines." As a result, generally speaking, only during the construction phase are companies required to file a prevention program.

During the operation phase, turbine maintenance is required. The companies that perform this maintenance in Quebec are not included on the list of sectors the CSST requires to submit a prevention program. Moreover, the status of wind turbines, as machines, means that the CSST does not stipulate the associated obligations in detail. Wind turbine operation and maintenance have an unclassified status.

Once a wind farm is up and running, during the approximately 20-year operation and maintenance phase, three major players become involved, each potentially following different prevention guidelines and practices (Table 5):

- Wind turbine manufacturer (essentially during the warranty period)
- Wind farm owner-operator
- Subcontractors who perform work occasionally

Table 5 – Players involved in wind turbine operation

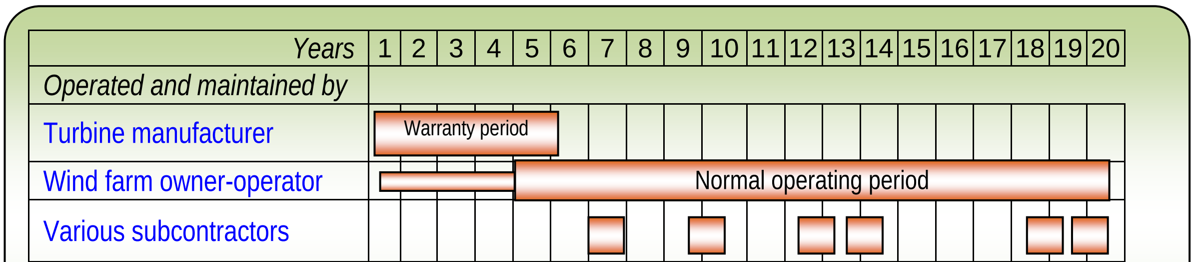

Chart showing functions and activity periods of various players involved in wind farm operation and maintenance.

Under current warranty practices, during the first few years following delivery of wind turbines in Quebec (the warranty generally covers a period of three to five years), most, if not all of the monitoring, operation and maintenance work is performed by the turbine manufacturer's team of technicians. The manufacturer trains its own staff to follow its working methods and applies the accident prevention and safety procedures it has adopted. If the manufacturer makes use of subcontractors, it requires the subcontractors' employees to follow its work methods and accident prevention and safety procedures. The wind farm owner-operator has no choice but to follow the manufacturer's methods during the warranty period, although it can also draw up its own summary of the accident prevention guidelines to be followed by all personnel who perform work on its farm.

When this study was done, only two recent farms had reached the end of their warranty period. All the others were still under warranty, which means that turbine maintenance was still being performed by the manufacturer.

4.2.1 From Legal Obligations to Workplace Practices

While the CSST's accident prevention program regulations do not apply across the board to all activities and companies in the wind energy sector, in practice, almost all of the companies involved should file such a program, as the CSST recommends.

Our research revealed that, in general, the companies involved in the two main types of wind farm activity—construction and operation/maintenance—do have the basic elements of an accident prevention program. In construction, the proportion of companies having a prevention plan is quite high. In operation/maintenance, on the other hand, some subcontractors that work occasionally but not primarily in the wind energy sector do not have prevention plans tailored to the needs of the sector.

The Quebec wind energy industry generally appears to have understood the need for accident prevention documentation, plans and recommendations. Most companies are able to show that they have the relevant material. However, it was noted that

- The level of detail of the plans varies significantly from one company to the next, and there is not really any standard.
- Plan presentation does not follow the basic structure recommended by the CSST. Moreover, some information is in English only, meaning that Quebec workers may well have trouble understanding it properly.
- When they do exist, these documents and plans are rarely posted and not easily accessible to workers and technicians, except sometimes in an ultrasimplified form.

Most wind energy industry players do not address the issue of accident prevention by taking the traditional approach recommended by the CSST, which sets out the main components of a prevention program as follows:

- Main hazards
- Regulations and standards to be followed to eliminate or control hazards
- Personal protection equipment to be worn by workers
- Monitoring and maintenance measures to be taken
- Training needs to be met, and resources required to meet them

In the *wind farm construction* sector, the presentation of accident prevention plans is fairly uniform and covers some of these points, but the construction phase lasts only a few months and these companies leave the farm once they have completed their work. In addition, many of them are already familiar with CSST requirements.

No doubt because wind turbines are such complex machines, close examination of operating and maintenance activities reveals a series of guidelines, explanations, instructions and recommendations specific to each task. However, at the other end of this accident prevention process there is usually a very basic overall prevention plan that sets out only the main prevention guidelines or recommended actions. This series of documents and plans is illustrated below (Figure 6), showing how they fit together as a whole to constitute an “accident prevention plan,” though without necessarily having the organizational structure recommended by the CSST.

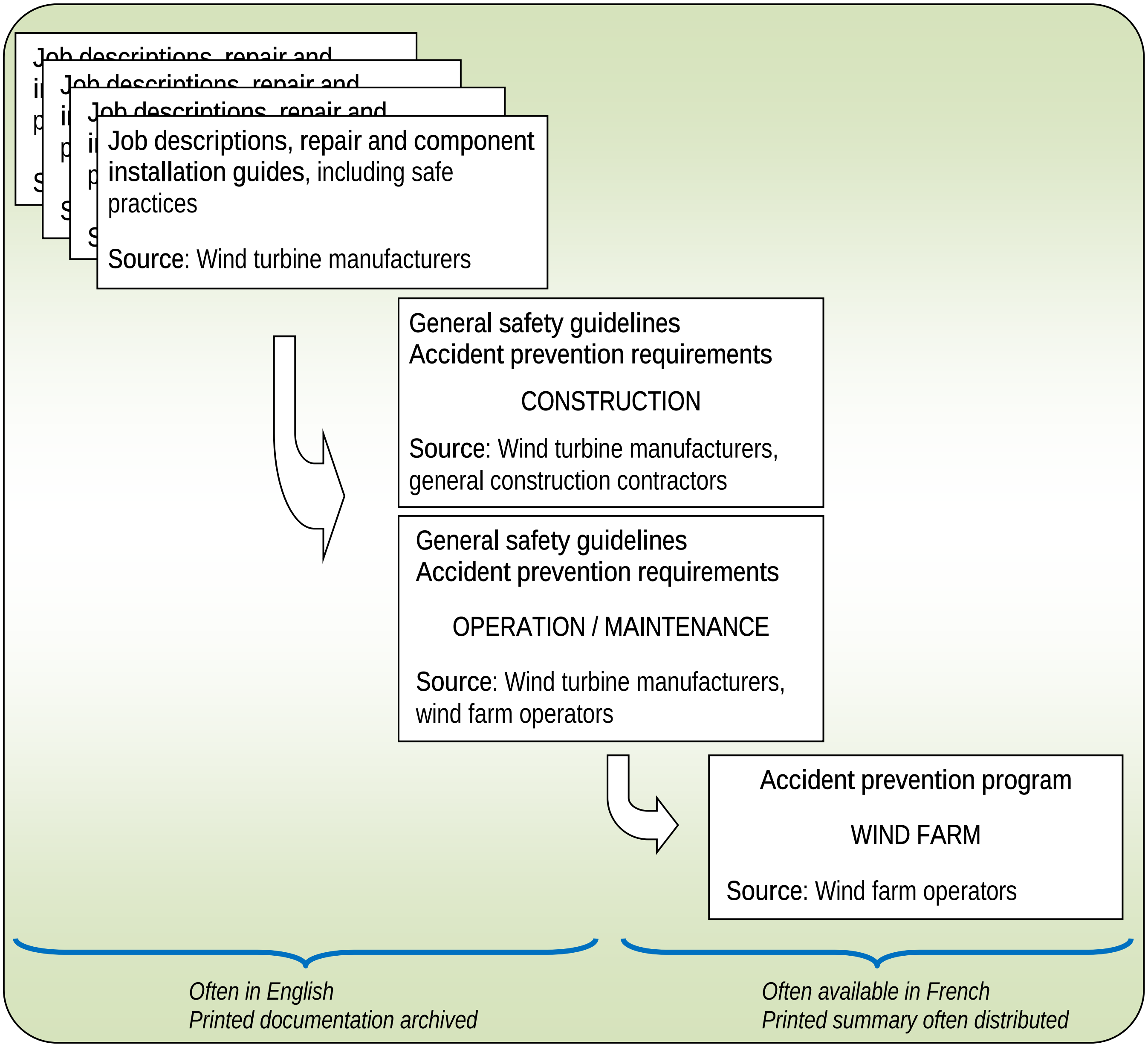

Figure 6 – Documents and plans required for an accident prevention program

Accident prevention plans, as defined by the CSST, are not common in the wind energy sector. Manufacturer-supplied documentation describing the various maintenance tasks and safe work procedures is used. In most cases, this extensive technical material is available only in English. The prevention measures described include lockout procedures. In addition to the procedures manual, wind farm operators draw up a summary of the general safety guidelines their staff must follow. An analysis of the practices of Quebec wind farm operators shows that virtually all of them produce this kind of summary, with some of them referring to it as an accident prevention plan. There is no standard presentation format, however, with the structure differing from one operator to the next.

4.2.2 Influence of Major Players in Defining Accident Prevention Plans

Wind turbine manufacturers play a major role in defining occupational safety and accident prevention measures, as they produce all the technical documentation. Generally speaking, they have a huge influence on the approach to safety and the vision and philosophy of prevention. During the *construction phase*, when many different companies are involved simultaneously on the same worksite, accident prevention measures generally follow a pre-established order. Usually the main contractor is the company that sets the occupational safety standards to be met by all subcontractors working on the site. A company having prevention standards lower than those required by the main contractor must comply with the higher standards. On the other hand, a company whose prevention standards are already more stringent than those set by the main contractor is free to maintain them or lower them to the main contractor's level.

4.3 Prevention Programs Elsewhere in the World

The organization of safety and accident prevention in the wind energy sector in Quebec is chiefly dictated by manufacturers and practices in other jurisdictions. Each country has its own specific OHS regulations and requirements. Similarly, each wind turbine manufacturer provides its teams with training in specific procedures. In general, what is described above reflects accident prevention protocols, documents and structures commonly found in operating wind farms, especially in Germany, the United Kingdom and the United States. In France, the government's work inspection unit issues recommendations for the wind energy sector, but does not go any further.[19] However, virtually all wind energy projects are designed by wind turbine manufacturers—in most cases, German, Spanish or Danish companies—and those manufacturers impose their own safety rules and methods. There does not seem to be, at least in France, any standard prevention plan, as the concept is understood in Quebec. Wind farm operators acknowledge this is one of the priority issues the industry and regulatory agencies must address as soon as possible.

4.4 Summary of Findings

In Quebec, ***accident prevention plans*** are found at the wind farm construction stage. There are also ***emergency response plans*** that set out what emergency response measures must be implemented. Once wind farms have been commissioned, operators establish their own accident prevention plans by synthesizing requirements from different sources: wind turbine manufacturers, Quebec regulations, specific working conditions (weather conditions, distance and isolation, availability of emergency services).

Most prevention plans take the working conditions specific to Quebec wind farms only partially into account, for two reasons. First, because the plans are primarily based on documentation produced by wind turbine manufacturers, the vast majority of which are European. Second, because most wind farm operators are international or North American companies that run farms in several countries. They therefore tend to impose accident prevention methods developed in the U.S.A. or Europe, where most of their farms are located, on all their farms.

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19. In France, the government's "*inspection du travail*" [work inspection] unit is responsible for conducting on-site inspections to ensure companies are complying with laws and regulations, including OHS regulations.

In many cases, it was noted in the field that workers and technicians are aware that an accident prevention plan exists; sometimes they've read a summary of it, but they have problems getting access to the plan's detailed guidelines and protocols. In other words, the company can meet the CSST's requirements and show that a plan exists, but only company managers have access to the plan and know its detailed provisions.

5. WIND TURBINE LOCKOUT

5.1 Methodological Approach

This part of the research project involved the following activities:

- Assessing current and future wind energy technology, on the basis of operating and maintenance guides published by manufacturers
- Identifying the constraints imposed by wind turbine manufacturers, by examining their documentation and conducting on-site observations
- Observing work performed on a construction site and on wind turbines undergoing maintenance
- Studying typical CSST lockout requirements in similar sectors to wind energy or with respect to similar machinery by examining CSST regulations, CSST newsletter articles and recent information campaigns
- Taking into account the views expressed by wind farm operators in interviews and at monitoring committee meetings
- Studying real practices, from the standpoint of wind farm operators, based on interviews with a Theolia wind farm operator, and demonstration of methods used on a European wind farm, based on an interview with a Boralex wind farm operator

5.2 Findings

5.2.1 Lockout – A CSST Priority

In recent years, the CSST has significantly increased its lockout procedure requirements and information campaigns. It may soon be paying closer attention to the wind energy sector. In Quebec, wind turbines are considered to be machines and must therefore comply with regulations governing machinery. This classification raises problems, however, as we will see below, because the reality in the wind energy sector is more complex.

5.2.2 Complexity of Modern Wind Energy Technology

Wind turbines are steadily getting larger and more powerful. Quebec's first wind farms, near Matane, had 750 kW machines with a height of 55 m. The newest turbines are 2.3 MW models that stand 100 m high at the hub. Furthermore, recent technological developments have made wind turbines considerably more sophisticated. A wind turbine is no longer a simple machine, but a complex assembly of more than 15 independent systems and over 2,000 components. Many subcomponents are independent machines in themselves. For example, the three-blade variable-pitch system is now completely independent and operated by its own dedicated systems incorporating batteries, controllers, safety mechanisms, etc. The rotation of the nacelle, which must always face into the wind, is also a fully independent system. Lastly, the new turbines can be operated remotely via a control centre, which can also run diagnostics on them. In short, a modern wind turbine is a remote-controlled, self-contained generating unit perched 100 m up in the air.

In a wind turbine designed to generate electricity, the risk of electric shock is always present. Voltages range from 110 V (controls, automation cabinets, etc.) to 15,000 V or even 25,000 V for the transformer output voltage feeding into the grid. The generator output voltage is around 600 V. The transformer can be installed in the nacelle, meaning a high-voltage hazard in the nacelle, or at the base of the tower. In a wind turbine, safety lockout chiefly has to do with electrical hazards.

Yet there are also mechanical hazards associated with a wind turbine, as the machine is designed to convert the kinetic energy of the wind into electrical energy by means of a mechanical converter consisting of blades, a rotating axis and a generator. In contrast with a machine in a factory, where the energy source (electrical, mechanical, thermal, etc.) can be controlled, the energy source of a wind turbine, i.e., the wind, is uncontrollable and even hard to predict locally. The solution to this problem is to control the turbine’s mechanical energy. Safety lockout of a wind turbine therefore also has a mechanical energy component.

It is hard to imagine completely de-energizing a modern wind turbine. Recent turbine designs cannot be made to face into the wind without electrical power, because of the technology they use. Moreover, the angle of the blades must be controlled continuously to adjust turbine power to the strength of the wind. So, barring major problems, a wind turbine must always be kept powered up for safety reasons, especially in high winds.

5.2.3 Specific Characteristics of Wind Turbine Lockout

The concept of lockout, advocated in Quebec by industry and required under regulatory standards, is based on total cutoff of the electrical supply and the use of mechanical locking to prevent any possibility of human error and any risk of accident to workers and technicians. However, virtually all of the wind turbines operating in Quebec were designed and manufactured in Europe, and the methods, tools and techniques used to prevent actions are, in practice, defined by these European designers and manufacturers.

In Europe, lockout procedures are used to isolate subassemblies (cells) rather than to cut off the entire power supply. The wind energy industry considers a turbine to be a complex set of many different subassemblies, each of which must be “isolated” or locked out separately or in a cascading sequence. Technicians will therefore lock out system subassemblies rather than the whole wind turbine. Mechanisms (conditional access keys) are used to progressively isolate specific parts of the turbine. As a result, the turbine is never locked out or de-energized in its entirety.

A further difference between lockout practice in Europe and North America is that in Europe, lockout is just one of several safety procedures used for maintenance, whereas in North America it is the prime means.

5.2.4 Wind Turbine Lockout Points

Operations on a wind turbine can be prevented, either through the control circuit or the power circuit, at the following points:

- Wind farm control centre (control circuit, remotely)

- Wind farm transformer substation (power circuit)
- Base of the tower (control and power circuits, several points)
- Nacelle (control and power circuits, several points)

Strictly speaking, however, only use of the power circuit to cut off the energy supply is considered to be a form of lockout, the use of the control circuit being regarded as a form of "maintained stop command" under Section 6.3 of Standard ISO 14118:2000.[20]

While these isolating points can vary from one wind turbine to another, these are the most common such points:

- Power supply line to the wind turbine or a subsection of the wind farm at the transformer substation (power)
- Shut-off control via the wind farm's central control system (control)
- High-voltage power cell (power)
- High-voltage isolating switch (power)
- Low-voltage main switch (power)
- Inverter cabinet (power)
- Control system cabinet (control)
- Forcing blade pitch into feathered position (control)
- Manually turning turbine away from prevailing winds (control)
- Mechanical blocking of rotor (power)
- Hub and variable-pitch electrical systems (power)

5.2.5 Lockout Problems Related to Manufacturers' Protection of Trade Secrets

The lockout issue is an awkward one, in particular because it is primarily determined by each manufacturer's proprietary technology. For instance, the industry is increasingly shifting toward synchronous generator wind turbines, which are very different (no mechanical reducer, oversized generator, power electronics, etc.) from the asynchronous machines commonly used up to now.

Given that lockout methods and procedures are closely tied to the technological concepts, automated functions and controls defined and designed by each manufacturer, control protocols, very often written in English, are kept secret. Accordingly, each manufacturer imposes its own procedures for isolating and locking out different parts of the turbine. The manufacturer also defines the work procedures for the maintenance, repair and inspection of the different turbine components. Consequently, these procedures vary from one manufacturer to the next, and it is somewhat unrealistic to believe there could be a standard lockout method for all wind turbines, given the wide range of differences in design and technology.

20. *ISO 14118:2000 – Safety of machinery – Prevention of unexpected start-up* (Geneva: ISO, 2000).

5.2.6 On-Site Observation of Lockout Methods

The Quebec wind energy industry, consulted in the field and during monitoring committee meetings, clearly expressed its stance in favour of allowing a wide range of different technologies and against the indiscriminate imposition on the industry of lockout methods currently used in other industrial sectors in Quebec. The basic principle supported by the industry was that, since wind turbines are a special type of machinery, they should enjoy a separate status different from that of other machines.

Despite these constraints and specific industry characteristics, a consensus seems to be emerging with respect to the following issues:

- The permanent and increasing presence of powerful, high-voltage currents in all wind turbines underscores that there is a serious electric shock and electrocution hazard for workers.
- Modern wind turbines are so technologically complex that it is virtually impossible for a technician to understand all the lockout procedures and to know, without prior consideration, which ones are appropriate in any given situation.
- The increasing number of lockout systems, specific to each manufacturer and even each type of turbine, makes it extremely hard for maintenance personnel to choose and quickly follow a specific procedure.

5.3 Summary

This exploratory study reveals that

- Lockout is a core issue in the effort to improve working conditions and prevent accidents in the wind energy industry.
- It is possible to improve the current situation while still respecting manufacturers' concerns about protecting their trade secrets and continuing to develop their technology.
- This is a complex issue, and most people involved do not seem to have adequate training to deal with it. Operation and maintenance handbooks that clearly explain the safety procedures to be followed need to be available in French to maintenance personnel at all times.
- More needs to be known about wind turbine operation, the related hazards and the appropriate lockout procedures. This new knowledge must be incorporated into accident prevention plans and lockout instructions.
- Efforts must be put into ensuring that maintenance personnel are properly trained.
- Given the fact that wind turbine maintenance procedures are highly complex and that training and posting appear to be inadequate ways of getting the required information across to the people who need it, it might be worthwhile to examine the possibility of using new media, such as tablets and laptops, to provide technicians with quick access to the information they need.

6. EMERGENCY EVACUATION LOGISTICS

6.1 Methodological Approach

This part of the research project concerned the very specific working conditions of wind energy sector employees in Quebec. Take the case of a worker injured while in a cramped space, one so small it could be classified as a confined space, several dozen metres above the ground. Under existing regulations, wind farm operators are required to have the capability to not only ensure the safety of their personnel, but also to evacuate them if necessary, which means they must be able to bring in not just first responders (ambulance crews), but sometimes also other more specialized rescue teams. In Quebec, with its long distances between far-flung regions and its low population density in the regions where wind farms are located, it is impossible to have specialized rescue teams on hand, and so the issue of rescuing and evacuating injured workers is significantly more complex than elsewhere and raises major challenges.

While evacuation protocols exist and are sometimes tested, they often reflect ideal conditions. In this research project, we did not have an opportunity to observe or conduct an emergency evacuation simulation in the field, which would have allowed us to rigorously analyse how it was organized and problems encountered and to draw conclusions. Given the absence of a field simulation exercise and the fact that no recent accidents requiring evacuation of injured workers have occurred in Quebec, we attempted to assess the risks based on what people involved in this type of emergency response had to say.

The research method followed was therefore to conduct interviews with people from the following groups:

Workers
Wind farm operators
Ambulance attendants
Health and social service agency workers
Firefighters
Sûreté du Québec provincial police officers
CSST inspectors
Members of regional rope access teams
Trainers certified in vertical rescue
Forestry workers with experience in geolocating meeting points
Regional 911 centre staff

In addition to holding meetings and interviews with those people, we brought some of them together with wind energy industry representatives (around 30 people in all) for a miniconference in Cap-Chat in June 2011. For most of the representatives of the emergency response and civil protection agencies that serve the wind farms, the conference was an opportunity to express their views on the safety situation and on the problems and challenges they face in the field. At the day-long event, a number of viewpoints were heard and discussed.

To illustrate what is involved in evacuating an injured worker from a wind turbine, here is a typical example of how an evacuation proceeds, in winter conditions, in the standard case of two technicians working alone in a wind turbine in a forested area, far from a main road. We put together this imagined scenario based on wind farm operators' evacuation protocols and interviews with emergency responders in the Gaspé.

1. Work accident occurs: technician injured in nacelle.
2. Fellow technician frees injured worker. Injured worker stabilized. Serious injury diagnosed. Two technicians isolated in nacelle. Uninjured technician tries to call for help.
3. Makes cellphone contact with employer-wind farm operator.
4. Makes cellphone contact with 911 emergency number. Hard to provide exact location. Tries to find turbine identification number.
5. Ambulance heads toward site.
6. Uninjured technician tries to prepare for evacuation of injured worker through rescue system.
7. Ambulance enters wind farm area, but has trouble finding right road because of snow (roads not mapped on GPS). Ambulance unable to go beyond snow clearance limit (referred to as "meeting point").
8. Wind farm safety team arrives, consisting of three people and small tracked vehicle with stretcher for moving injured worker from base of turbine tower.
9. Ambulance attendants identify meeting point by geolocation, station themselves at that spot on access road, being unable to reach tower, and wait for injured worker to be brought to them there.
10. Lockout procedures are followed by operator's team to ensure everyone's safety.
11. Through 911 service, telephone link established between nacelle, where injured worker is, and doctor, so that information can be exchanged regarding injured worker's symptoms.
12. Injured technician's state deteriorates, and emergency teams consider other means of evacuation from nacelle, such as airlift.
13. Sûreté du Québec provincial police issue alert and their helicopter takes off from Saint-Hubert Airport, 2 hours 30 minutes' flying time from wind farm.
14. Injured worker is prepared for emergency evacuation by operator's rescue team.
15. Worker is finally brought to meeting point and handed over to ambulance crew before helicopter arrives. Helicopter mission cancelled.

During the field observations, special attention was devoted to the issue of emergency evacuation.

6.2 Findings

- The long time it takes for an ambulance to respond to an emergency call from a wind farm is symptomatic of the emergency response problem in Quebec, where ambulance services are generally located far away from wind farm sites. A georeferenced tracking system for points where rescue teams and ambulance crews can meet, originally developed for forestry workers, has been adapted to the case of wind farms. But the chances that ambulance drivers will lose their way in the maze of small roads and end up wasting precious time are high, especially given that wind farms are not mapped on the GPS systems found in most ambulances, in the Gaspé at least.

- The protocols governing worker communication with their dispatch centre or company are still fuzzy. For instance, on an isolated wind farm with a hundred or so turbines, often two technicians working together will still not know the exact identification number of the turbine they are working on, even though this information is absolutely essential to effective emergency response in the event of an accident.
- For serious injuries, emergency helicopter airlift services are essential, but not readily available or operational in the eastern part of the Gaspé. The only such service is operated by the Sûreté du Québec provincial police force out of Saint-Hubert Airport, five hours' flying time from the Gaspé.

6.3 Recommendations

In light of these findings, the research team decided to make two recommendations applicable to most Quebec wind farms, which are very large in size and chiefly located in rural or forested areas having complex networks of unmarked roads:

1. Equip all ambulances serving wind farm regions with GPS systems that include maps of small rural roads so that ambulance drivers can quickly and easily find the wind turbine where an accident has happened.

2. Carry out more injured-worker evacuation training exercises, in particular involving the Sûreté du Québec's helicopter airlift service. Most wind farms are located in isolated places, often in remote and sometimes mountainous areas. There are several possible methods or techniques for quick evacuation of a seriously injured worker, including evacuation by a specially trained team of rope access technicians and airlift evacuation by helicopter. In all cases, weather conditions, rescue team availability and other factors must be taken into account when deciding what means to use. Training exercises of this complexity are rarely organized, however, and emergency response services need to have a better understanding of what evacuation method to choose when responding to an accident.

7. GENERAL SUMMARY

7.1 Accident Analysis

No organization anywhere in the world keeps an updated scientific database on occupational health and safety in the wind energy industry. In the United Kingdom, RenewableUK (formerly known as BWEA, British Wind Energy Association) is the organization that does the best monitoring; however, not only does it seem to be limited to the U.K., but our research team's request for access to its data was turned down. The fact that the only accessible source of OHS data is maintained by an association of anti-wind energy activists, the Caithness Windfarm Information Forum (CWIF), makes the lack of data all the more glaring.

In Quebec and the rest of Canada, the almost total absence of wind farm accident reports over the last 15 years suggests a lack of monitoring and accident reporting. According to the Sûreté du Québec helicopter crew members we spoke with, the fact that the Quebec wind energy industry has not reported any serious accidents so far may in part explain its limited interest in accident prevention and rescue practices.

Faced with this shortage of data, the research team conducted systematic international monitoring, chiefly via the Web, in order to put together as accurate a picture as possible of the hazards and accidents related to work in the wind energy industry. These hazards and accidents are chiefly related to

- Falls, associated with working at heights
- Collisions with objects that have a significant mass or fall from a height
- Electric shock and electrocution, associated with high-voltage electrical power
- Heart attacks, associated with climbing turbine towers

7.2 Analysis of Workplace Reality

The wind energy industry, despite its recent strong growth in Quebec and a number of countries, is still in its infancy, and working conditions in the sector are poorly documented. In Quebec, furthermore, a number of special factors create working conditions that differ somewhat from those found elsewhere in the world. For instance:

- Virtually all equipment used is designed and manufactured abroad.
- Quebec wind farms tend to be much larger than those elsewhere in the world.
- Winter weather conditions and the remoteness of the farms are further major constraints.

Among the weather phenomena and work situations found more frequently in Quebec, the following are worth noting:

- There is an almost systematic build-up in winter of ice on the turbine blades, resulting in blocks of ice being thrown off that are a hazard for workers approaching the turbine tower.

- Many wind turbines are installed in wooded, isolated areas, making it hard for rescue vehicles to find their exact location visually.
- Skidoos or tracked or other special vehicles must be used to reach wind turbines in winter because many access roads are only partially cleared, meaning that regular road vehicles cannot reach the towers. These means of transport must also be used to move injured workers.
- In winter, work must sometimes be performed around the turbine and in the tower in temperatures that can be very cold outside, but quite high inside the nacelle (temperature contrast, work clothes and harnesses that must be changed while working, etc.).

7.3 Analysis of Accident Prevention Practices

No doubt because the industry is still so young, accident data and a large part of the regulations inappropriately confuse and group together the following two distinct phases:

- Wind farm construction phase, i.e., the fairly short, predetermined period during which construction companies install the turbines at the wind farm
- Wind turbine operation phase, i.e., the 20-year period during which specialized companies operate and maintain the turbines

Accident prevention practices in the wind energy industry are somewhat limited in comparison with other sectors. Prevention programs are not very detailed and are a long way from meeting the requirements and good practices advocated by the CSST.

7.4 Lockout

The large wind turbines installed in Quebec and the rest of Canada are all imported from abroad, chiefly from Germany and Denmark. Even the turbines made by General Electric in the United States are designed in Europe. Only the low-tech, oversize components, such as blades and towers, are made here. Lockout methods and practices are therefore defined and imposed by European design engineers. However, European and North American conceptions of lockout are not the same. And these independent electrical generating units, perched over 80 m above the ground, are such complex machines that locking them out completely, as lockout is understood in Quebec, is simply not feasible. The nacelle of a wind turbine is similar to a mini-factory, having many different subassemblies. The European approach to what we call “lockout” in Quebec is to isolate certain components or parts of the turbine, but not the whole machine.

The case of elevators, which are starting to be incorporated into wind turbines erected in Quebec, is a good example of this difference. As much as possible, elevators must be kept operational, which means that power to the turbine as a whole cannot be turned off. Wind turbine manufacturers therefore lay down procedures for isolating specific cells, or subassemblies, according to a protocol that depends on the work to be done. The manufacturers almost never consider completely cutting off the power to a turbine, except under extraordinary circumstances.

With respect to lockout, this study has shown that

- The risks of work-related electric shock or electrocution are already high and continue to increase. Accident prevention focusing on electricity is therefore necessary and should be made a priority for wind turbine workers.
- Lockout procedures are complex and differ significantly from the conventional lockout procedures taught and practised in Quebec in other industries. Wind turbine technicians and operators therefore require appropriate training in these specific methods and procedures, as an essential part of accident prevention.
- A further complicating factor that increases the risks is that maintenance technicians, especially subcontractors, sometimes have to work on different types or makes of turbines. Lockout procedures vary from one manufacturer to the next, but also depending on which of the two major technologies is used: with a multiplier or without. Technicians (or subcontractors), even when well trained, can be confused by the wide variety of protocols to be followed.

7.5 Emergency Evacuation Logistics

During the operation phase, the main risks arise when workers are on or in the structure, that is, either the tower or the nacelle, approximately 80 m above the ground. Our research shows that four steps or actions must be performed successfully if an injured worker is to be evacuated efficiently from a wind farm in Quebec:

1. Moving the injured worker down to the base of the tower, which requires special equipment and appropriate training of the other workers at the site.
2. Quick arrival of an ambulance, even if the site is isolated, which requires communication, navigation and transportation equipment that enables the ambulance driver to reach the injured worker as fast as possible.
3. Roads that are passable even in winter, while planning for the use of a special means of transport over the snow if the access road to the turbine, from a meeting point with the ambulance crew, has not been cleared.
4. Availability of airlift by helicopter, with specially trained rescue crews, if the injured worker cannot be brought down to the base of the tower or transported over land.

According to the results of our consultations with various stakeholders, Step 1 is performed satisfactorily in Quebec. Step 2 can be a problem because some Quebec ambulances are not equipped with GPS systems that have the wind farms on their maps. The task of identifying and geolocating specific meeting points is being carried out by the forestry industry, which will help in the performance of Step 3. There is no Step 4 capability at present, as only the Sûreté du Québec provincial police force has significant helicopter airlift resources, and their base is located at around five hours' flying time from most Quebec wind farms. However, the Sûreté du Québec is well aware of the need to make this rescue service available to the wind energy industry and its workers and has proposed establishing specific protocols, jointly with the industry, that would include an alert channel and regular training exercises for its helicopter rescue team on airlift evacuations from wind turbines.

7.6 Conclusions and Recommendations

Albeit exploratory, this first study of the Quebec wind energy sector has produced an assessment of the state of the occupational health and safety situation in the industry and the hazards to which its workers are exposed. We were able to draw the following conclusions:

- The wind farm construction stage, which lasts around two years, should not be lumped together with the normal operation phase. Construction sites are relatively well organized and inspected, when it comes to OHS, but this fairly brief period is distinct from the around 20-year wind turbine operation phase that follows.
- The main hazards faced by wind energy workers are associated with working at heights, high-voltage electricity, moving parts in a cramped space and the remoteness of wind farm locations.
- The special conditions that apply to working on wind turbines in Quebec, including weather and isolation, increase the job risks, but accident prevention programs do not take these specific conditions sufficiently into account.
- The existing resources for evacuating seriously injured workers from isolated wind turbines are insufficient and have limited operational capability. Only the Sûreté du Québec provincial police force has a helicopter airlift service, while local firefighters are not equipped or trained to rescue injured workers from wind turbines.

The main recommendations to come out of this study are set out in Table 6.

Table 6 – Summary of recommendations

Recommendations	Implementation proposals
Accident prevention plans Encourage wind farm operators to draw up accident prevention plans, tailored to Quebec working conditions, that include emergency response plans, and make sure workers can consult the plans easily.	Design a standard accident prevention plan, in French, adapted to the wind energy sector, that can be distributed to wind farm operators. In this connection, a pilot project initiated by the research team, in cooperation with the Wind Energy Techno-Centre, led to the proposal and testing of certain elements to be incorporated into a prevention plan (hazard identification and accident prevention plan development software, accident or critical incident reporting form). In CEGEP courses, improve wind energy sector worker training by introducing the concept of an accident prevention plan, what it should contain and how it should be applied.
Lockout Provide more information and training in French.	Provide more specific, more detailed lockout protocols and methods, and make them available, in French, to all personnel (including subcontractors). In CEGEP courses, expand training by introducing the concept of lockout, what it covers and how it should be applied in the specific case of the wind energy sector.
Evacuation and rescue protocols Draw up and implement rescue protocols for handling seriously injured workers who need to be evacuated with the help of a specially trained rescue team or airlifted by helicopter.	Work with the Sûreté du Québec provincial police to draw up appropriate emergency response and rescue protocols. Conduct at least one real training exercise per year in Quebec.
Case analyses In an area where the CSST does little prevention or inspection, except on wind farm construction worksites, continue to identify hazards through field observations and case analyses.	Continue to collect data on work accidents at wind farms in order to compile solid statistics. Continue observation and analysis of work performed on wind turbines, with a view to better documenting work methods used and recommending appropriate accident prevention procedures.

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APPENDIX A – DATABASE

Last updated in June 2011 based on CWIF update of April 6, 2011.

Certainty	Nature of accident by cause	Nature of task	Number of workers involved	Accident result type	Date	Name of wind farm	Location	Country	Year farm built
1.0	electrical	maintenance	1	injury	2000-04-01	Palm Springs, CA	land	U.S.A.	
1.0	moving part	maintenance	1	injury	2000-10-26	Kern County, CA	land	U.S.A.	
1.0	traffic	transport	1	fatal	2000-12-19	Erwitte, Westfalen	land	Germany	
1.0	falling object	misc.	1	injury	2001-10-09	Brithdir Mawr eco-commune, Newport, Wales	land	U.K.	
1.0	electrical	maintenance	1	injury	2002-07-01	Sigean, Aude	land	France	
0.5	fall	maintenance	1	fatal	2002-07-10	Eemmeerdijk, Zeewolds, Flevoland	land	Netherlands	
0.5	fall	maintenance	1	injury	2002-07-10	Eemmeerdijk, Zeewolds, Flevoland	land	Netherlands	
1.0	traffic	transport	1	transport	2002-11-19	Dahlenburg, Lueneburger	land	Germany	
1.0	electrical	maintenance	1	injury	2002-11-19	NorthWind?, Byron, CA	land	U.S.A.	1999
1.0	NOS	construction	1	misc.	2002-12-31	Horns Rev Offshore Wind Farm	sea	Denmark	Dec-02
0.5	falling object	construction	1	fatal	2003-05-13	Burlington, ND	land	U.S.A.	
1.0	crane collapse	construction	1	misc.	2003-07-28	Windpark Fiebig/Ostfriesland	land	Germany	
1.0	fire	operation	2	injury	2003-07-30	Castilla y León	land	Spain	
1.0	fire	maintenance	3	fire	2003-08-15	Schwochel bei Ahrensbök im Kreis Ostholstein/Schleswig-Holstein	land	Germany	
1.0	electrical	NOS	1	fatal	2003-09-18	Tres Vaqueros Wind Farm, Byron, Altamont Pass, CA	land	U.S.A.	
0.5	fall	maintenance	1	fatal	2003-10-15	Neuruppen, Brandenburg	land	Germany	
1.0	NOS	NOS	1	injury	2003-12-31	Cabo Vilán Wind Farm, Galicia	land	Spain	
1.0	NOS	NOS	1	fatal	2004-01-07			Sweden	
1.0	NOS	NOS	1	fatal	2004-01-07	Hontalbilla de Almazán, Soria		Spain	
1.0	fall	NOS	1	fatal	2004-07-16	Wittmund in Ostfriesland/Niedersachsen (Lower Saxony)		Germany	
1.0	falling object	construction	1	injury	2004-07-28	Windpark Schwirzheim nahe Büdesheim bei Prüm im Kreis Bitburg-Prüm/Rheinland-Pfalz		Germany	
1.0	fall	maintenance	1	fatal	2004-09-14	Meyersdale, Somerset, PA	land	U.S.A.	2003
1.0	physical exertion	maintenance	1	injury	2004-10-01	North Hoyle Offshore Wind Farm	sea	U.K.	Dec-03
0.5	traffic	construction	1	transport	2004-11-21	Tiskalaw, IL	land	U.S.A.	
0.5	fire	maintenance	2	fire	2004-12-07	Schaller, near Storm Lake, IA	land	U.S.A.	
1.0	fall	maintenance	1	injury	2005-01-01	Scroby Sands Offshore Wind Farm	sea	U.K.	March-04
1.0	physical exertion	maintenance	1	injury	2005-01-01	North Hoyle Offshore Wind Farm	sea	U.K.	Dec-03
1.0	moving part	maintenance	1	injury	2005-01-01	Scroby Sands Offshore Wind Farm	sea	U.K.	March-04
1.0	moving part	maintenance	1	injury	2005-02-02	Voigtstedt/Thüringen		Germany	
1.0	physical exertion	maintenance	1	injury	2005-04-01	North Hoyle Offshore Wind Farm	sea	U.K.	Dec-03
0.5	impact	operation	1	injury	2005-05-01	North Hoyle Offshore Wind Farm	sea	U.K.	Dec-03
1.0	moving part	maintenance	1	fatal	2005-05-07	Marsberg–Erlingshausen–		Germany	

Certainty	Nature of accident by cause	Nature of task	Number of workers involved	Accident result type	Date	Name of wind farm	Location	Country	Year farm built
						Hochsauerlandkreis, Westphalia			
1.0	moving part	maintenance	1	injury	2005-05-07	Marsberg–Erlingshausen–Hochsauerlandkreis, Westphalia		Germany	
1.0	traffic	construction	1	transport	2005-10-18	A' Chleit, Kintyre, Scotland	land	U.K.	
1.0	traffic	transport	1	transport	2005-11-05	Wells Fargo, ND		U.S.A.	
1.0	fall	maintenance	1	fatal	2005-11-11	East Ridge Wind Farm, Chandler, MN	land	U.S.A.	2006
1.0	fire	maintenance	2	injury	2005-11-11	East Ridge Wind Farm, Chandler, MN	land	U.S.A.	2006
1.0	traffic	construction	1	transport	2005-11-29	A941 Elgin-Rothes road at Drumbain, less than a mile from Rothes, Moray, Scotland	land	U.K.	
1.0	traffic	construction	1	transport	2005-12-02	Larrabee, IA	land	U.S.A.	2006
1.0	NOS	NOS	2	injury	2005-12-22	Woolnorth Windfarm, Tasmania		Australia	
1.0	impact	maintenance	4	injury	2006-01-01	Scroby Sands Offshore Wind Farm	sea	U.K.	March-04
1.0	physical exertion	maintenance	2	injury	2006-01-01	Scroby Sands Offshore Wind Farm	sea	U.K.	March-04
1.0	fire	maintenance	1	injury	2006-01-01	Scroby Sands Offshore Wind Farm	sea	U.K.	March-04
0.5	NOS	maintenance	4	injury	2006-01-01	Kentish Flats Offshore Wind Farm	sea	U.K.	Oct-05
1.0	moving part	maintenance	1	injury	2006-01-01	Scroby Sands Offshore Wind Farm	sea	U.K.	March-04
1.0	moving part	maintenance	1	fatal	2006-01-10	Bording and Karup		Denmark	
1.0	falling object	maintenance	1	misc.	2006-01-16	Locust Ridge I Wind Farm, Pennysylvania	land	U.S.A.	
1.0	traffic	construction	1	fatal	2006-01-23	Port Burwell, ON		Canada	
1.0	NOS	maintenance	1	injury	2006-02-18	Buchbrunn, Würzburg, Bavaria		Germany	
0.5	NOS	maintenance	1	injury	2006-06-01	North Hoyle Offshore Wind Farm	sea	U.K.	Dec-03
1.0	traffic	construction	1	transport	2006-08-24	Portland, OR	land	U.S.A.	
1.0	moving part	construction	1	injury	2006-08-25	Beatrice Oil Field, Highlands, Scotland		U.K.	
1.0	NOS	maintenance	1	fatal	2006-10-22	Gemeinde Schlangen in Kreis Lippe, North Rhine/Westphalia		Germany	
1.0	electrical	maintenance	1	injury	2006-11-27	Scroby Sands, Norfolk, England		U.K.	
1.0	traffic	construction	1	fatal	2006-12-13	Falls Township, Bucks County, PA	land	U.S.A.	
1.0	impact	construction	1	injury	2006-12-19	Johnstown, Cambria County, PA		U.S.A.	
1.0	impact	maintenance	4	injury	2007-01-01	North Hoyle Offshore Wind Farm	sea	U.K.	Dec-03
1.0	impact	maintenance	1	injury	2007-01-01	Scroby Sands Offshore Wind Farm	sea	U.K.	March-04
1.0	impact	maintenance	1	injury	2007-01-01	Scroby Sands Offshore Wind Farm	sea	U.K.	March-04
1.0	falling object	maintenance	1	injury	2007-01-01	Kentish Flats Offshore Wind Farm	sea	U.K.	Oct-05
1.0	physical exertion	maintenance	2	injury	2007-01-01	Scroby Sands Offshore Wind Farm	sea	U.K.	March-04
1.0	moving part	maintenance	1	injury	2007-01-01	Kentish Flats Offshore Wind Farm	sea	U.K.	Oct-05
1.0	physical exertion	maintenance	1	injury	2007-02-14	Barrow Offshore Wind Farm	sea	U.K.	July-06

Certainty	Nature of accident by cause	Nature of task	Number of workers involved	Accident result type	Date	Name of wind farm	Location	Country	Year farm built
1.0	falling object	transport	1	injury	2007-02-23	Unspecified port, TX	land	U.S.A.	
1.0	electrical	NOS	1	injury	2007-02-25	Lake Bonney Wind Farm, Tantanoola, Southeast Australia	land	Australia	
1.0	impact	construction	1	injury	2007-05-15	Dalswinton, Dumfries and Galloway, Scotland		U.K.	
1.0	fall	construction	1	fatal	2007-05-22	Earlsburn Wind Farm, Stirling, Scotland		U.K.	
0.5	fall	maintenance	1	injury	2007-05-23	Barrow Offshore Wind Farm	sea	U.K.	July-06
1.0	moving part	maintenance	1	injury	2007-07-03	Oasis, Mojave, CA	land	U.S.A.	2004
0.5	crane collapse	maintenance	1	injury	2007-07-30	NoordzeeWind, IJmuiden, near Amsterdam	sea	Netherlands	2006
1.0	fall	maintenance	1	fatal	2007-08-25	Klondike III Wind Project, Wasco, OR	land	U.S.A.	2007
1.0	fall	maintenance	1	injury	2007-08-25	Klondike III Wind Project, Wasco, OR	land	U.S.A.	2007
1.0	sea	construction	38	misc.	2007-09-16	Robin Rigg Offshore Wind Farm, Solway Firth, Dumfries and Galloway, Scotland	sea	U.K.	2010
1.0	impact	maintenance	1	injury	2007-09-18	Barrow Offshore Wind Farm	sea	U.K.	July-06
1.0	traffic	transport	1	transport	2007-09-19	A87 Kyle to Portree Road, Skye, Highlands, Scotland	land	U.K.	
1.0	falling object	maintenance	1	injury	2007-09-26	Barrow Offshore Wind Farm	sea	U.K.	July-06
1.0	traffic	transport	1	transport	2007-10-15	Texas	land	U.S.A.	
1.0	traffic	construction	1	transport	2007-10-16	Ashurst		N.Z.	
0.5	moving part	maintenance	1	injury	2007-10-22	Barrow Offshore Wind Farm	sea	U.K.	July-06
1.0	traffic	construction	1	transport	2007-11-07	Lincoln County, KS		U.S.A.	
1.0	fall	maintenance	1	injury	2007-11-11	Oasis (2004) or Difwind VIII (1999) or Difwind VI (1999), Mojave, CA	land	U.S.A.	
1.0	physical exertion	maintenance	1	injury	2007-12-21	Barrow Offshore Wind Farm	sea	U.K.	July-06
1.0	fire	maintenance	1	injury	2008-01-01	Kentish Flats Offshore Wind Farm	sea	U.K.	
1.0	moving part	maintenance	1	injury	2008-01-01	Kentish Flats Offshore Wind Farm	sea	U.K.	Oct-05
1.0	fire	maintenance	1	fire	2008-01-15	Mount Storm, West Virginia	land	U.S.A.	2008
1.0	electrical	maintenance	1	injury	2008-01-21	Scroby Sands Offshore Wind Farm	sea	U.K.	March-04
1.0	sea	maintenance	23	transport	2008-01-31	Barrow Offshore Wind Farm	sea	U.K.	July-06
1.0	electrical	maintenance	1	injury	2008-02-09	Buffalo Gap (assumed), Taylor County, TX	land	U.S.A.	2005
1.0	impact	maintenance	2	injury	2008-02-21	Barrow Offshore Wind Farm	sea	U.K.	July-06
1.0	fall	construction	1	injury	2008-03-03	Edom Hills Wind Park, Cathedral City, CA	land	U.S.A.	2008
1.0	crane collapse	construction	1	misc.	2008-03-03	GroWind Park, Eemshaven	land	Netherlands	
1.0	fall	misc.	1	injury	2008-03-06	Cathedral City, CA	land	U.S.A.	
0.5	traffic	maintenance	1	fatal	2008-03-18	Cefn Croes, Wales	land	U.K.	June-05
1.0	fall	maintenance	1	misc.	2008-03-26	Palm Springs, CA	land	U.S.A.	
1.0	fall	maintenance	1	injury	2008-04-16	Abilene, Taylor County, TX	land	U.S.A.	
1.0	sea	research	1	fatal	2008-05-12	Off Delaware coast	sea	U.S.A.	
1.0	sea	research	1	injury	2008-05-12	Off Delaware coast	sea	U.S.A.	
1.0	fall	research	2	fatal	2008-05-17	Jersey Atlantic Wind Farm, Atlantic City, NJ	sea	U.S.A.	2005
1.0	fall	research	2	injury	2008-05-17	Jersey Atlantic Wind Farm, Atlantic City, NJ	sea	U.S.A.	2005
1.0	fall	maintenance	1	fatal	2008-06-24	Osório Wind Farm		Brazil	
1.0	falling	construction	1	injury	2008-07-14	Brahamasagara		India	

Certainty	Nature of accident by cause	Nature of task	Number of workers involved	Accident result type	Date	Name of wind farm	Location	Country	Year farm built
	object								
1.0	moving part	misc.	1	injury	2008-07-15	Tehachapi, CA	land	U.S.A.	
0.5	electrical	maintenance	1	injury	2008-08-02	Silver Star Wind Farm, Eastland and Erath counties, TX		U.S.A.	
1.0	traffic	construction	1	fatal	2008-09-17	St. Cloud, Minnesota	land	U.S.A.	
1.0	explosion	construction	1	injury	2008-09-24	Parc Les Crêtes, La Tourlandry	land	France	Jan-09
1.0	impact	construction	1	fatal	2008-10-09	Barton Windmill Project, Worth County, IA		U.S.A.	
1.0	falling object	research	1	fatal	2008-11-09	Gulf Winds Project, Kennedy County, TX	land	U.S.A.	
1.0	sea	construction	10	transport	2008-11-13	Rhyl Flats Offshore Wind Farm, North Wales	sea	U.K.	
1.0	crane collapse	construction	1	injury	2008-11-23	Winnebago County, MN		U.S.A.	
0.5	moving part	construction	1	injury	2008-11-23	Robin Rigg Offshore Wind Farm, Solway Firth, Scotland	sea	U.K.	2010
1.0	explosion	construction	3	injury	2008-12-01	Elkhorn Ridge, Bloomfield, NE		U.S.A.	
1.0	impact	construction	1	fatal	2008-12-17	Santa Clarita, Los Angeles, CA		U.S.A.	
1.0	electrical	maintenance	1	injury	2008-12-17	Dexter, Mower County, MN	land	U.S.A.	
1.0	electrical	maintenance	2	injury	2009-01-26	Parc de Saint Simon, Clastres, Aisne	land	France	April-04
1.0	sea	construction	42	misc.	2009-01-30	Robin Rigg, Irish Sea	sea	U.K.	
1.0	fall	construction	1	injury	2009-02-04	Pico de Meda Wind Farm, Galicia		Spain	
1.0	NOS	construction	1	fatal	2009-02-04	Pico de Meda Wind Farm, Galicia		Spain	
0.5	NOS	maintenance	1	injury	2009-04-15	Kern County, CA		U.S.A.	
1.0	electrical	maintenance	1	fatal	2009-05-10	Sleeping Bear, Woodward, OK	land	U.S.A.	2008
1.0	traffic	transport	1	transport	2009-06-07	Kellog, IA	land	U.S.A.	
1.0	contaminant	construction	1	fatal	2009-07-21	Wind farm construction site, Pictou County, NS		Canada	
1.0	traffic	transport	2	transport	2009-07-31	Oxford, southern Nebraska		U.S.A.	
0.5	electrical	maintenance	4	injury	2009-08-15	Texas	land	U.S.A.	
1.0	NOS	maintenance	1	fatal	2009-09-16	Causewaymire Wind Farm, Caithness, Scotland		U.K.	
1.0	crane collapse	maintenance	1	injury	2009-09-22	Dutch Hill/Cohocton Wind Farm, Cohocton, NY	land	U.S.A.	2008
1.0	fall	construction	1	injury	2009-09-23	Gunfleet Sands, Clacton, North Sea, England	sea	U.K.	April-10
1.0	electrical	maintenance	1	injury	2009-11-03	Murdochville, Mont-Copper, QC	land	Canada	June-05
1.0	fall	maintenance	1	injury	2009-11-07	Winnebago I, Thompson or Forst City, IA	land	U.S.A.	Jan-08
1.0	impact	construction	1	fatal	2009-11-13	Greater Gabbard Offshore Wind Farm, England	sea	U.K.	Jan-12
1.0	impact	construction	1	injury	2009-11-13	Greater Gabbard Offshore Wind Farm, England	sea	U.K.	Jan-12
1.0	moving part	maintenance	1	injury	2009-12-08	AeroTurbine, North Palm Springs, CA	land	U.S.A.	1989
1.0	NOS	maintenance	1	fatal	2010-02-17	Derrybrien, South Galway	land	Ireland	Oct-05
1.0	fall	misc.	1	injury	2010-02-18		land	CA, U.S.A.	
1.0	falling object	construction	1	misc.	2010-03-08	Hennickendorf, Brandenburg	land	Germany	
1.0	electrical	maintenance	3	injury	2010-04-18	Campo Indian Reservation turbines, CA	land	U.S.A.	2005
1.0	NOS	maintenance	1	fatal	2010-04-20	Toufflers	land	France	Dec-93

Certainty	Nature of accident by cause	Nature of task	Number of workers involved	Accident result type	Date	Name of wind farm	Location	Country	Year farm built
1.0	falling object	construction	1	fatal	2010-05-21	Greater Gabbard Offshore Wind Farm	sea	U.K.	summer 2009
1.0	falling object	construction	1	injury	2010-05-21	Greater Gabbard Offshore Wind Farm	sea	U.K.	summer 2009
1.0	crane collapse	maintenance	1	injury	2010-06-20	Port Alma, Merlin, ON	land	Canada	Nov-08
1.0	falling object	construction	2	misc.	2010-08-01	Walney Offshore Wind Farm, England	sea	U.K.	2011
1.0	traffic	transport	1	transport	2010-09-06	Baileyville Wind Farm, Forreston, Ogle County, IL	land	U.S.A.	Dec-10
0.5	electrical	construction	1	injury	2010-10-01	Cayuga Ridge, IL	land	U.S.A.	2010
1.0	traffic	construction	1	fatal	2010-10-12	Wind turbine construction site near Kimball, SD	land	U.S.A.	Sept-10
1.0	falling object	maintenance	1	misc.	2010-10-21	Le Grand Camp	land	France	
1.0	traffic	transport	1	transport	2010-10-22	Barhill, Ayrshire, Scotland	land	U.K.	
1.0	traffic	transport	1	transport	2010-12-07	Sheffield Wind Park, VT	land	U.S.A.	Dec-10
1.0	traffic	transport	1	transport	2010-12-09	Te Uku, near Raglan	land	N.Z.	Jan-11
1.0	fall	maintenance	1	injury	2010-12-16	Parc à Pouille-les-Coteaux (Beauséjour or Mésanger II)	land	France	

APPENDIX B – ACCIDENT OR INCIDENT REPORT FORM

Part 1A – Accident or Incident Report

The purpose of this database is to encourage information sharing so that a better understanding may be gained of where and how the main accident risks arise. It is hoped that, as a result, effective accident prevention measures will be taken by the industry, workers and the wind energy sector in general.

Instructions for filling in form: Select from the multiple-choice lists that appear when you hover your cursor over the grey boxes. The definitions can be found at the end of the form.

Event Details		
Date (dd/mm/yyyy) / /	**Time** (hh:mm)	Occurred how long after start of shift?
Type: Sélectionner	**Was incident caused by part falling from turbine (or might have been)?**	Sélectionner
Seriousness by type, as applicable:	Accident or Sélectionner; Incident or Sélectionner; Secondary effects Sélectionner *If other, specify:*	
Type of accident: Sélectionner	*If other, specify:*	

Seriousness of Event

Select the level of seriousness of the event that caused injury and/or damage by choosing from the dropdown list on the right the level that best describes the most serious impact that resulted.

Impact	Number of people/Type of injury					Extent of damage	Impact (check)	Choose
	First aid	*Low (stoppage)*	*0–3 days*	*Major*	*Fatal*			
Low	1–3	1				Tolerable		Sélectionner
Medium	4+	2–9	1			Stoppage – Repairs made during shift		
High		10+	2–9	1		Stoppage – Repair / replacement on site		
Severe			10+	2+	1	Unrepairable without demobilizing or major delays or warning public		

Workplace Details		
Place Sélection terre-mer Sélectionner *If other, specify:*	**Work phase** Sélectionner *If other, specify:*	**Type of work** Sélectionner *If other, specify:*

Worker and Injury Details	
Role of employee: Sélectionner	*If other, specify:*
Occupation: Sélectionner	*If other, specify:*
Age (years)**:**	
Competency: Qualifications Sélectionner *List or specify, if appropriate:*	Experience in field (approx. number of years):

Description of Accident or Incident
Description of situation

Further Information Provided Voluntarily	
The information given below shall be treated confidentially and shall not appear in any report or on the Web. It shall only be used for research purposes and shall be handled in accordance with the rules of ethics established by the Université du Québec à Rimouski and the IRSST.	
Name:	
Position:	**Company:**
E-mail:	**Tel.:**
Date form filled in (dd/mm/yyyy): / /	**Reporting step:** Sélectionner

APPENDIX C – OBSERVATION REPORT

Observation Report – IRSST-UQAR Research Project

DATE: December 16, 2009
PLACE: Montagne de Rivière-au-Renard

Construction site of two 2.5 MW REpower wind turbines for TCE, Rivière-au-Renard, Gaspé[21]

Observations and Report

Anthony Lajus and Jean-Louis Chaumel

PROGRESS REPORT TO DATE

1 turbine completed
1 turbine being assembled

OBSERVATIONS

Winter working conditions (wind, snow, cold)
Several companies working on site simultaneously

- REpower (turbine manufacturer, 2 people)
- Borea (general construction contractor, about 10 people)
- Groupe Ohmega (electricity, about 14 people)
- KR Wind (crane operation and supervision, 3 people)
- RES (installation supervision, about 3 people)
- Hydro-Québec (2 people)
- Fibre Opt. (2 people)

Working language: Primarily English
Worksite meetings: Mornings at 7 a.m. and afternoons at 4 p.m.
Main risks observed: Accidents related to handling heavy loads, communication errors
Impact of weather conditions: Work is slower. Many heating units scattered around site. Predetermined maximum wind speed limit, decision to suspend work taken by main crane.

[21] According to a January 2014 news release, the new name of REpower Systems SE is Senvion.

Accident prevention plans in force

- With RES in charge of the installation, its prevention plan had to be followed by any parties having lower standards
- RES supervised safety and security (site access)
- Large document detailing all work procedures (rarely consulted, it seemed)
- The worksite (like every worksite, according to RES) had its own specific prevention plan (a few pages)

Conduct of workers on site

Personal protective equipment worn by everyone.
Some people were working under booms of operating cranes.

LOCKOUT

The initial energizing of the wind turbine was overseen by a group of three:

- Hydro-Québec
- RES electrical engineer
- REpower (manufacturer)

It is very rare for a wind turbine to be de-energized after this. Verification and testing require stopping and starting various systems, with the sections in question being isolated electrically (subassembly lockout by means of conditional access keys).

PHOTOS


KR Wind
KR Wind Safety Rules
Correct positioning
Check the documentation for ground bearing pressure.
Assess the ground bearing pressure.
Position all cranes on suitable mattresses or outrigger plates.
Assume responsibility and avoid accidents!
Correct lifting
Never overload the equipment.
Ensure to position the load correctly.
Use your common sense!
Correct rigging
Check all lifting equipment prior to use.
Control wear and tear and avoid using lifting equipment over sharp edges or similar.
Use your profound knowledge!
Correct service and maintenan
Protect the equipment.
Comply with and report all service
Think of your colleagues!
Correct safety equipment
Use required safety equipment including personal protective equipment.
Follow all other regulations prevailing on site.
Focus on safety!
KR Wind


KR Wind